
# Fermi GeVガンマ線衛星による3年間の成果

**Sep. 30, 2011@ICRR**

**(Multi-Messenger Astrophysics and CTA)**

**T. Mizuno**

**(広島大学　理学部->**

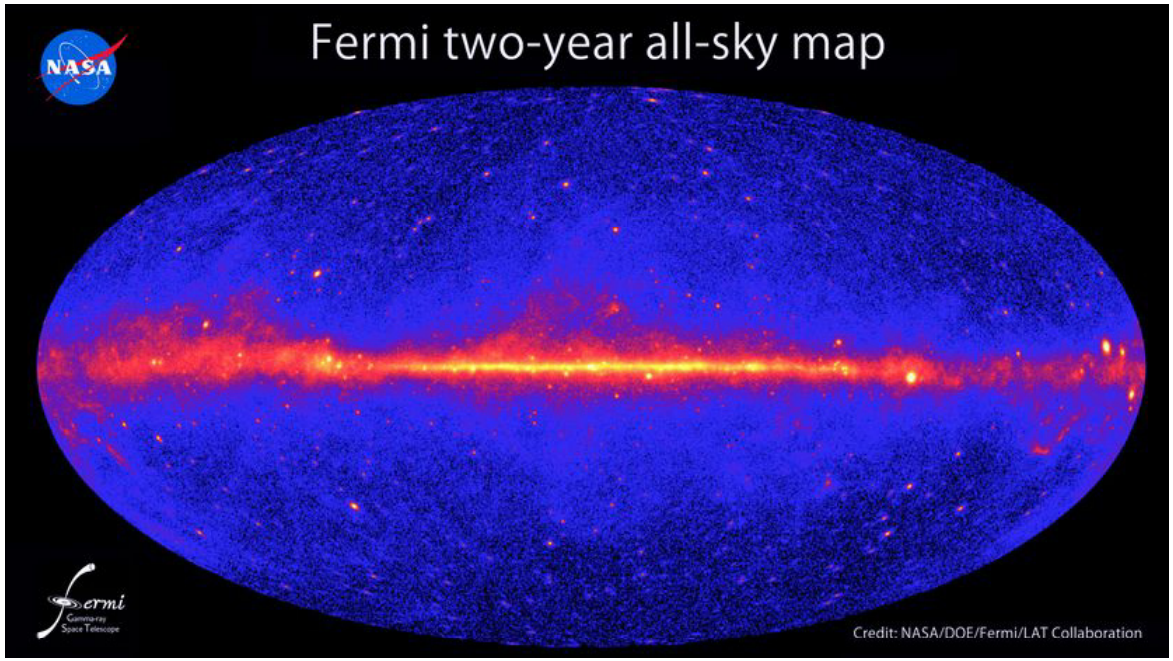
**宇宙科学センター)**

***On behalf of the Fermi-LAT collaboration***

# Fermi Gamma-ray Space Telescope

- **Fermi = LAT + GBM**
- **LAT = "GeV" Gamma-ray Space Telescope (20 MeV ~ >300 GeV )**


**Cape Canaveral, Florida**

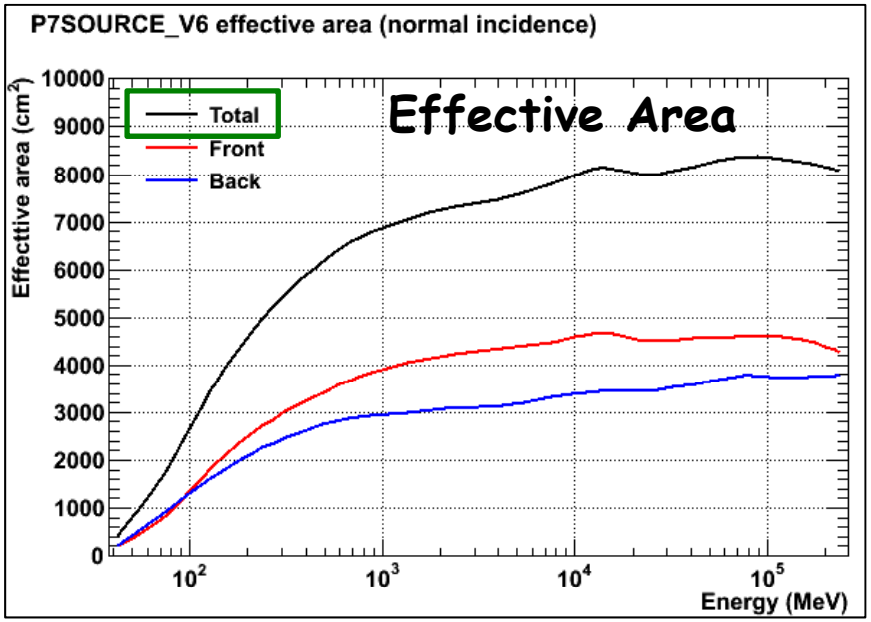


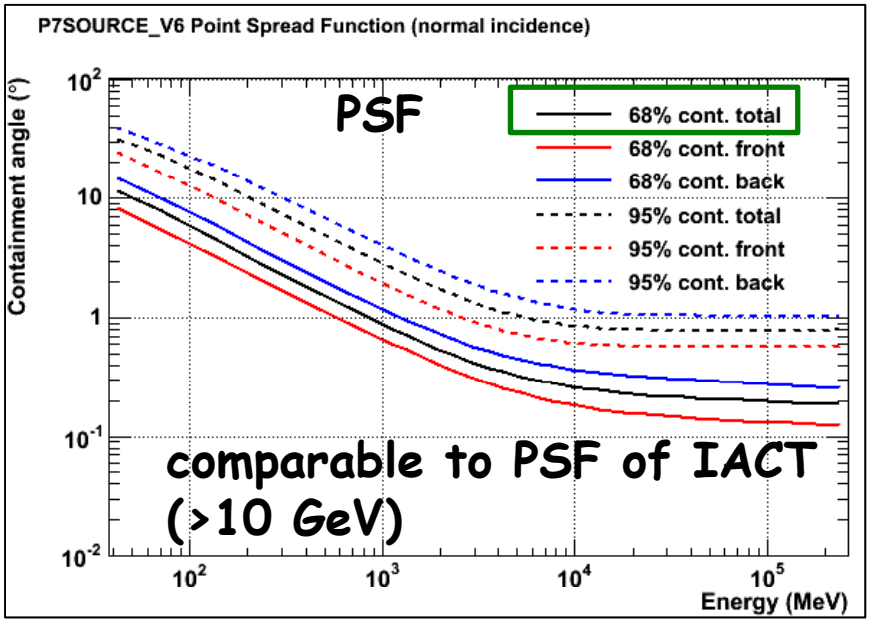

**1873 sources**
**Abdo+, ApJS submitted**
**arXiv:1108.1435**

# Fermi-LAT Performance

- **New Dataset and Response (Pass7)**
  - **Improved Aeff in low Energy**
  - **In-orbit calibration of PSF**

**http://www.slac.stanford.edu/exp/glast/groups/canda/lat_Performance.htm**



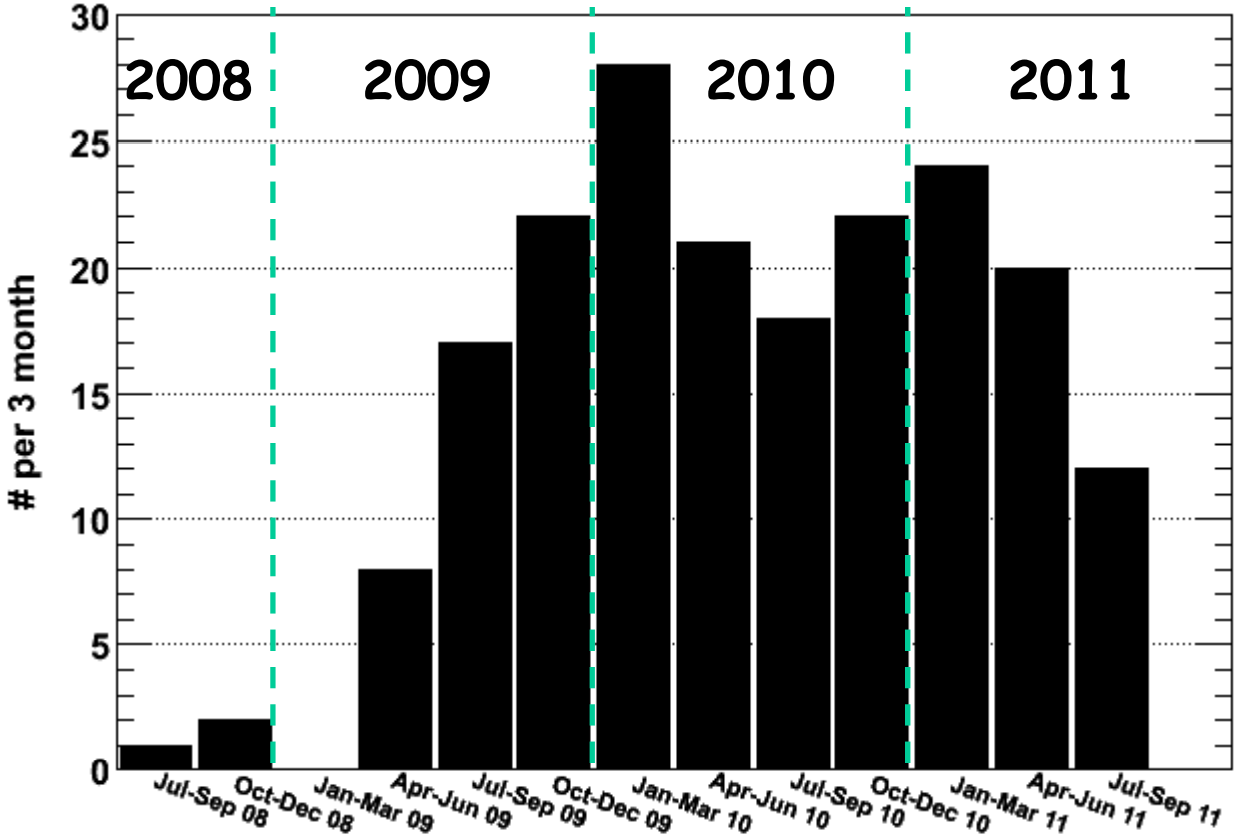




**1 year Integral Sensitivity (>10GeV): ~0.05 Crab (Atwood+09)**

# Fermi-LAT Publications

- **Publications by Fermi-LAT members**

(Cat I+II+III, as of mid-Sep. 2011)




~200 papers already published

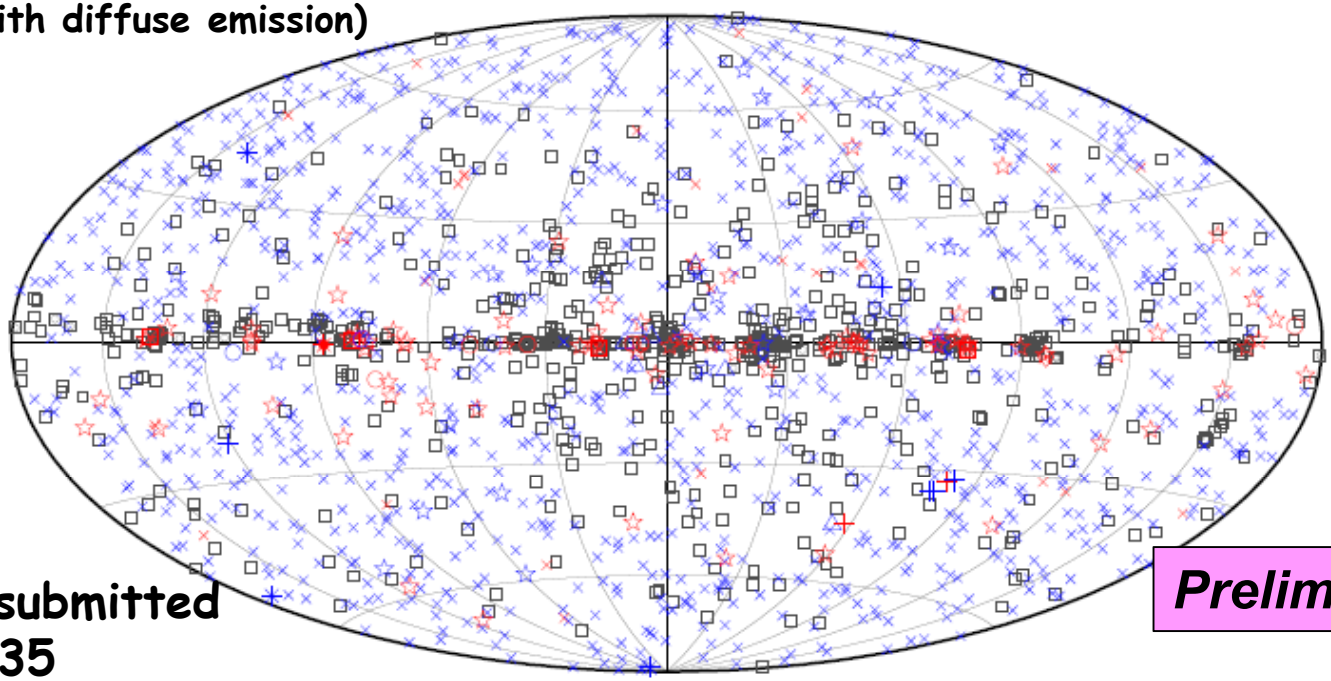
6-7 papers/month

http://www-glast.stanford.edu/cgi-bin/pubpub

# 2FGL: Second Source Catalog

- **1873 sources (~4σ significance)**
  - **127 firm identifications and 1170 reliable associations**
  - **576 unassociated with known γ-ray source class**

please pay attention to flags (e.g., 126 possibly confused with diffuse emission)



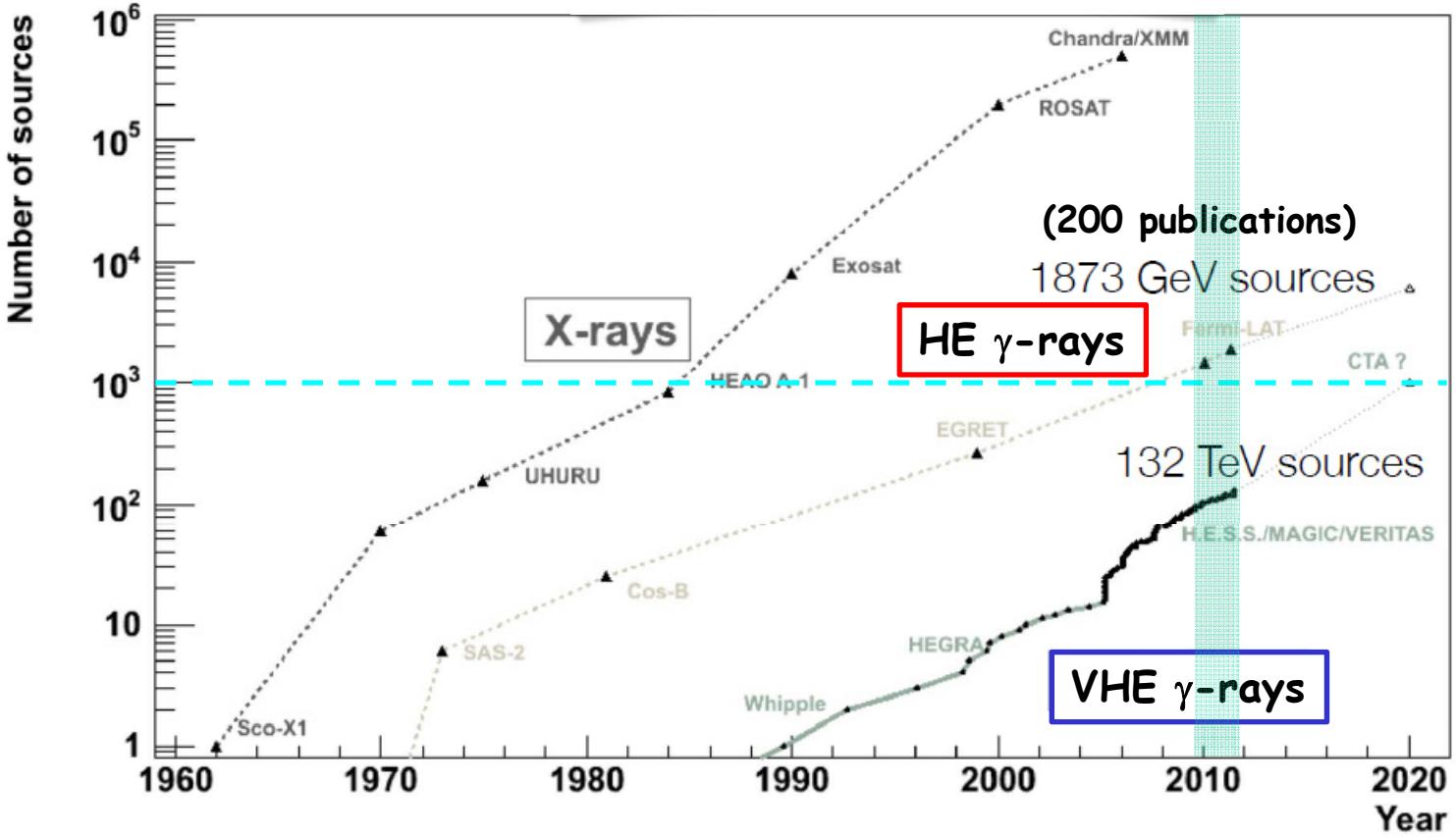
Abdo+, ApJS submitted
arXiv:1108.1435

***Preliminary***

| | | |
|---|---|---|
| ▫ No association | ▫ Possible association with SNR or PWN | |
| × AGN | ☆ Pulsar | △ Globular cluster |
| ✳ Starburst Gal | ◈ PWN | ⊠ HMB |
| + Galaxy | ○ SNR | ✷ Nova |

# Kifune Plot

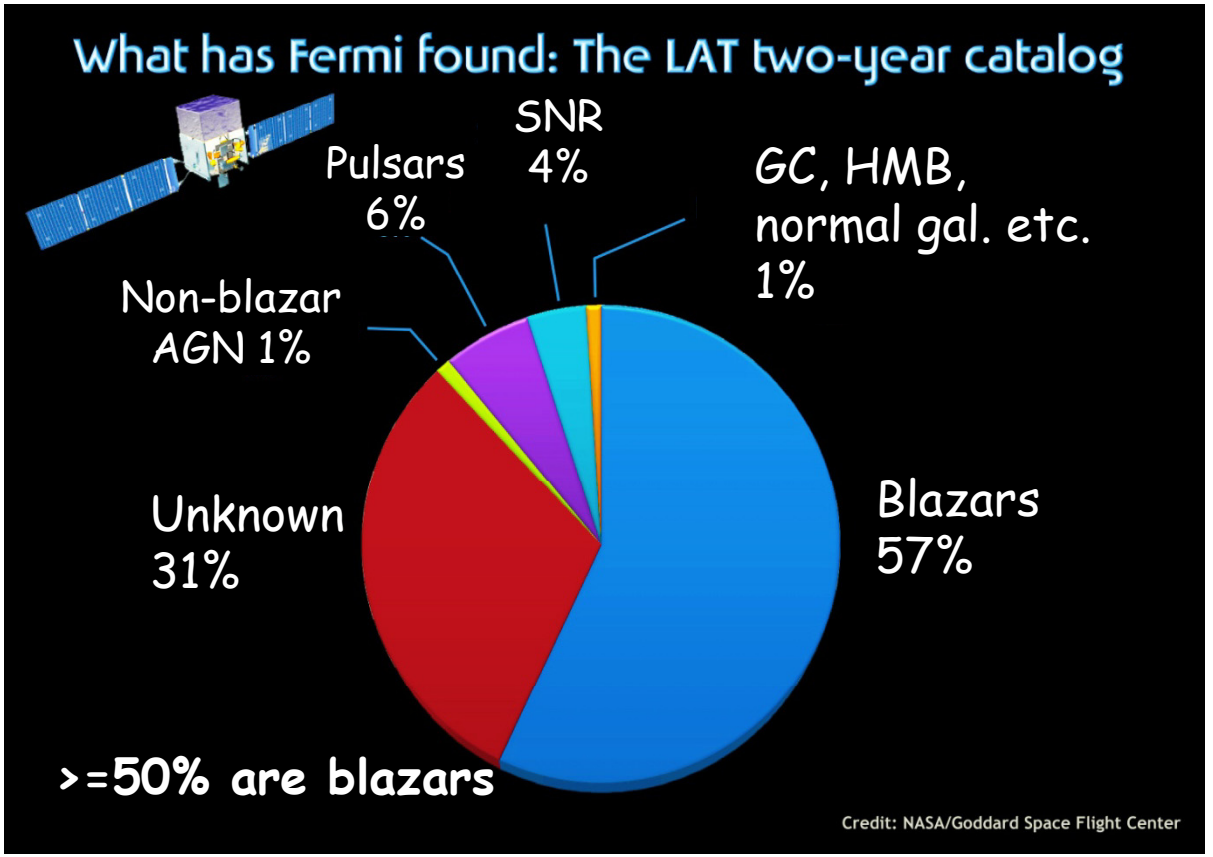
- # of sources exponentially increases in GeV
- Future: 1000 sources in TeV by CTA!?




T. Mizuno et al.

# Source Classes in 2FGL

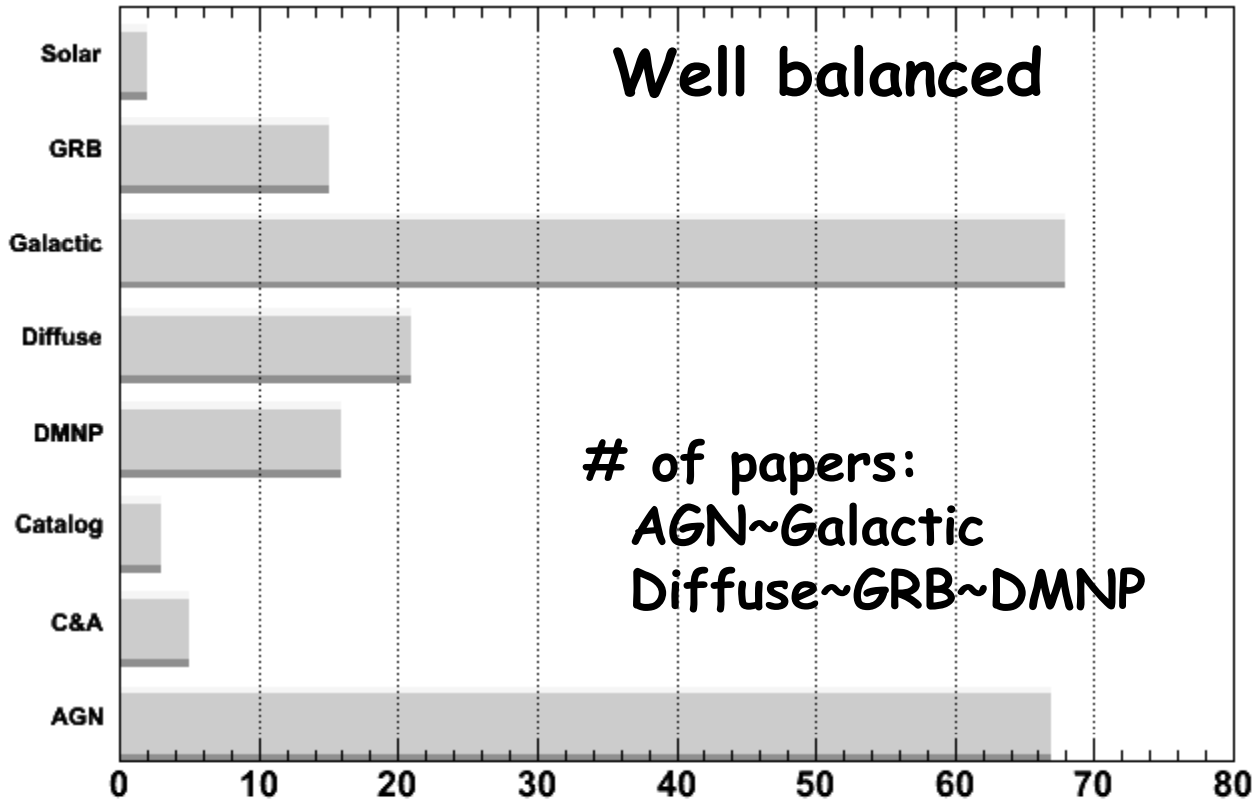
- # of known blazars and pulsars continue to grow
- 12 spatially extended sources (LMC/SMC, SNR and PWN)



# Source Classes in Fermi-LAT Publications

- **Publications by Fermi-LAT members**

  (Cat I+II+III, as of mid-Sep. 2011)



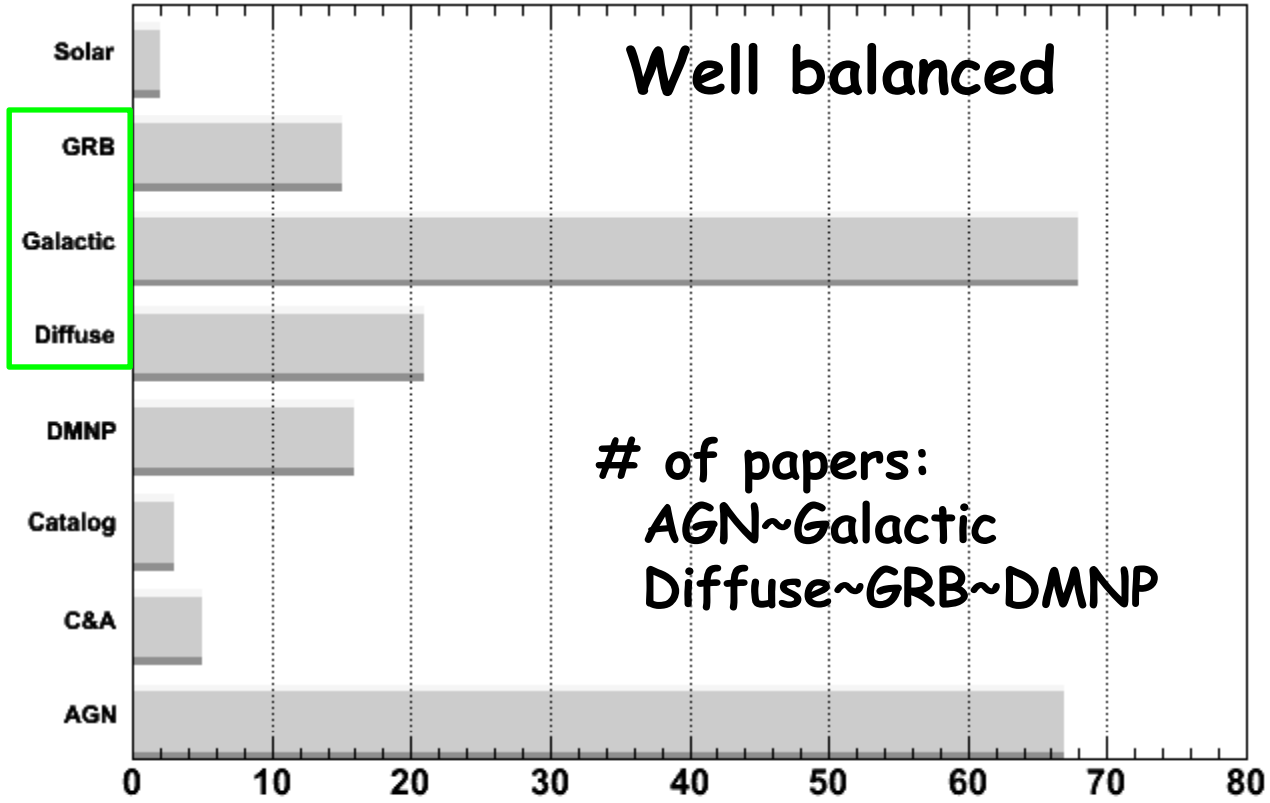

http://www-glast.stanford.edu/cgi-bin/pubpub

# Source Classes in Fermi-LAT Publications

- **Publications by Fermi-LAT members**

  (Cat I+II+III, as of mid-Sep. 2011)

covered by this talk




http://www-glast.stanford.edu/cgi-bin/pubpub

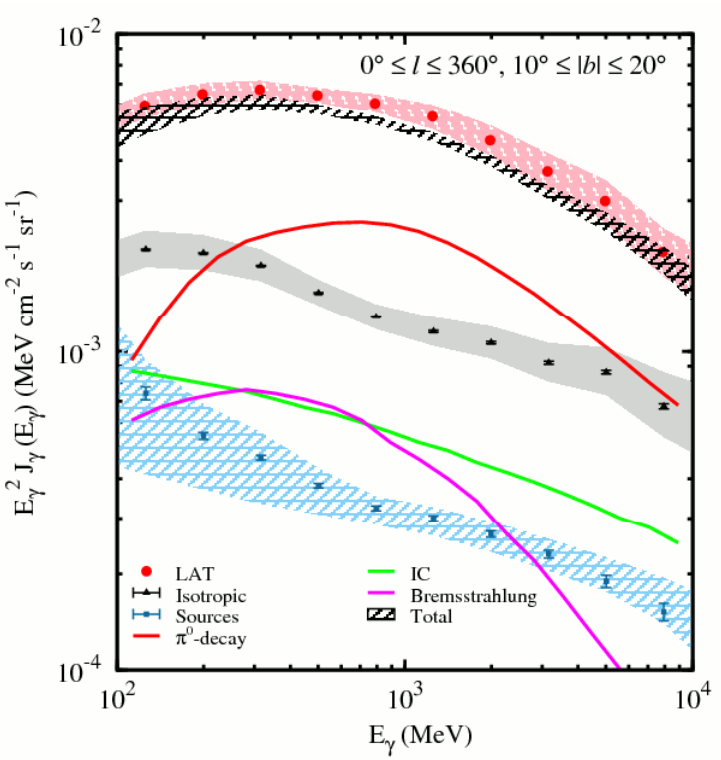
# Diffuse Emission Seen by LAT

- **Local diffuse emission is compatible with directly measured CRs**

- **"dark gas" is confirmed by Fermi-LAT data**
- **More CRs than expected in outer Galaxy**

  Abdo+10, ApJ 710, 133
  Ackermann+11, ApJ 726, 81

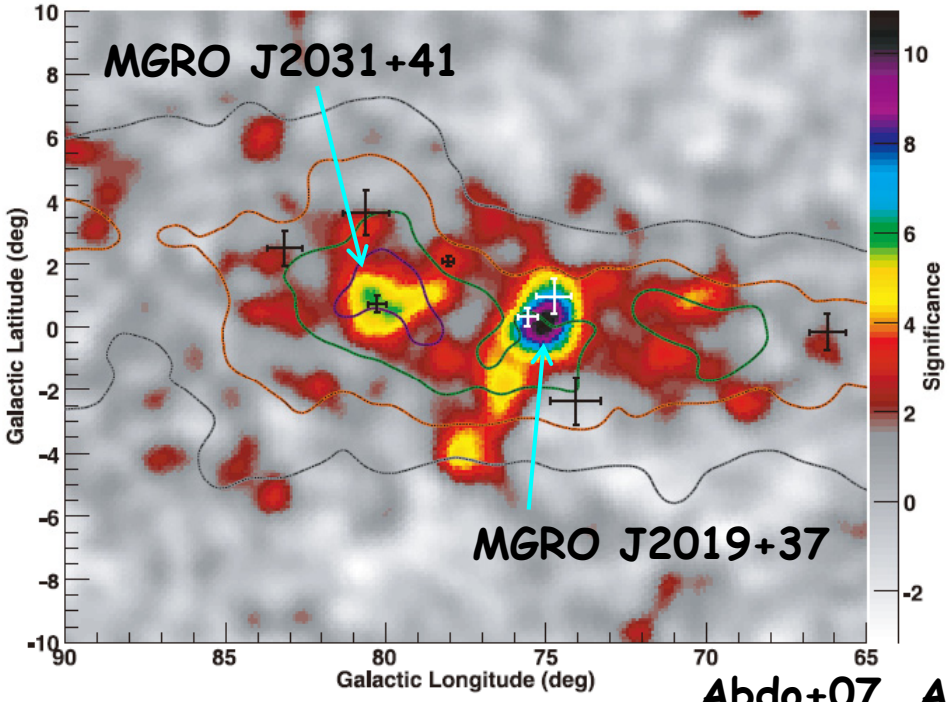
- **Freshly-accelerated CRs in Cygnus region**

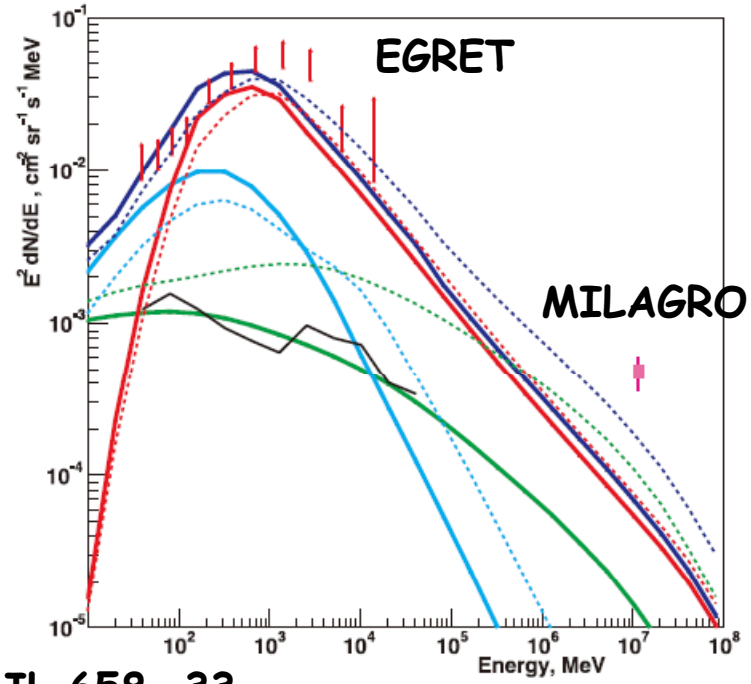



Abdo+09, PRL 103, 251101
(CA: Johannesson, Porter, Strong)

# The Cygnus Region (MILAGRO)

- Very rich region of massive-star formation at 1.4 kpc
- Two sources + diffuse emission at TeV (MILAGRO)
  - correlation with matter density
  - diffuse flux exceeds the prediction by local CR



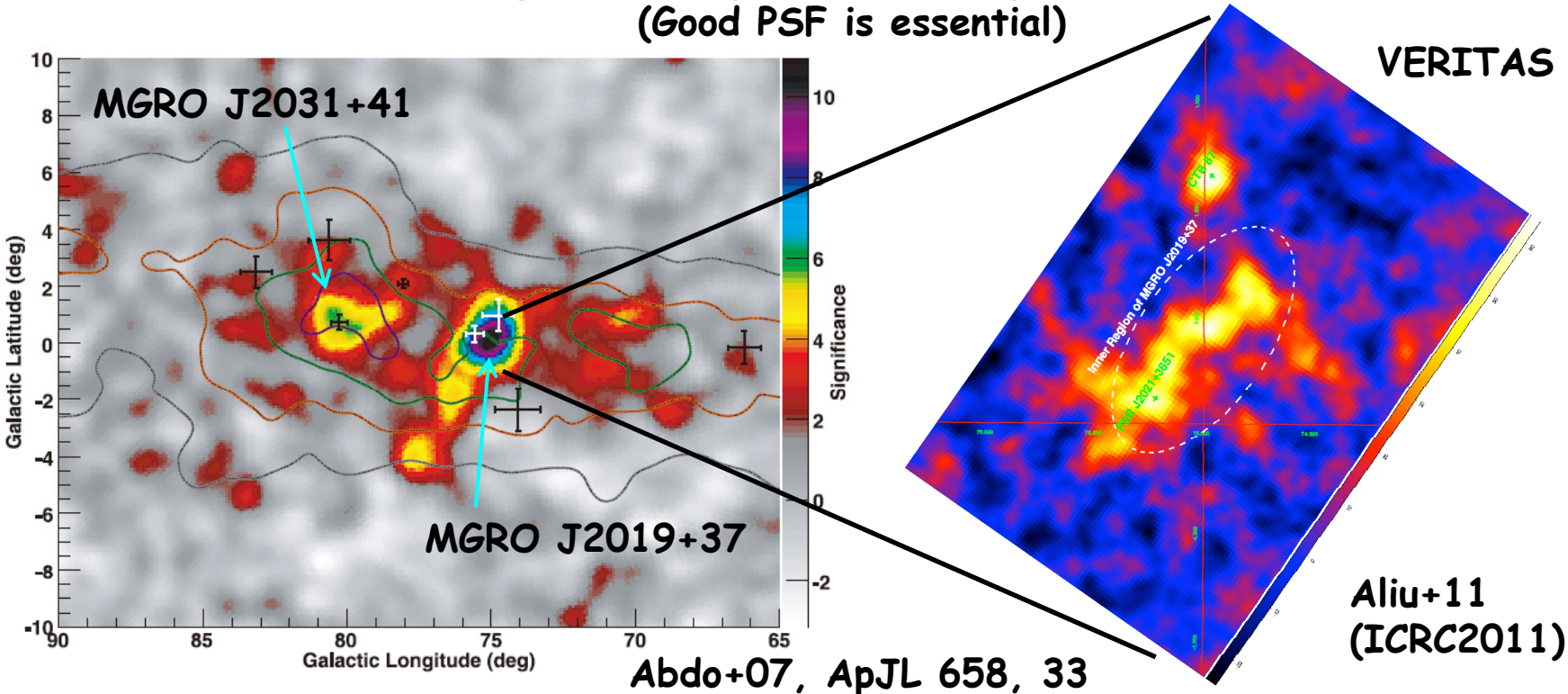




Abdo+07, ApJL 658, 33
Abdo+08, ApJ 688, 1078

# The Cygnus Region (VERITAS)

- Very rich region of massive-star formation at 1.4 kpc
- Cyg OB1 association seen by VERITAS
  - CTB87 resolved
  - plus complex region, likely powered by multiple sources

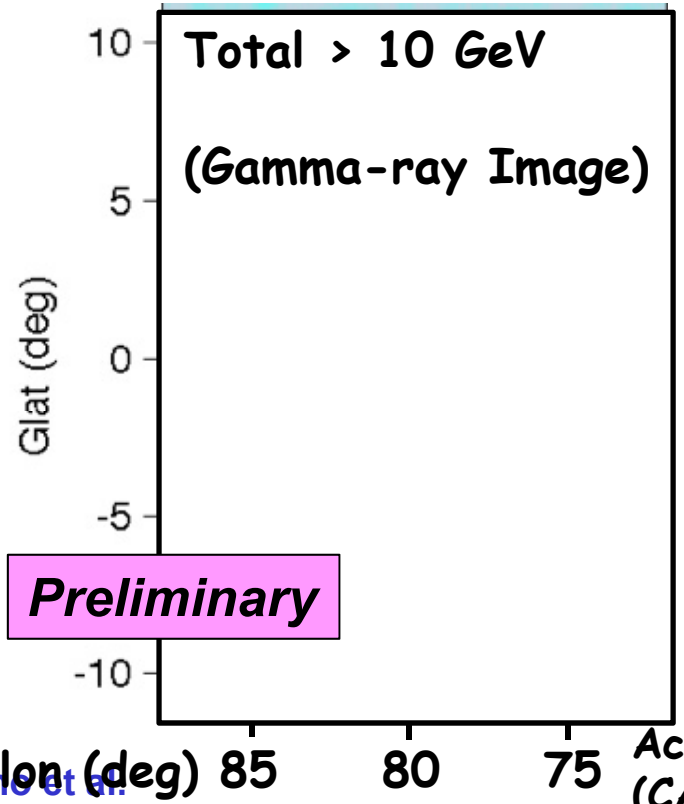
(Good PSF is essential)

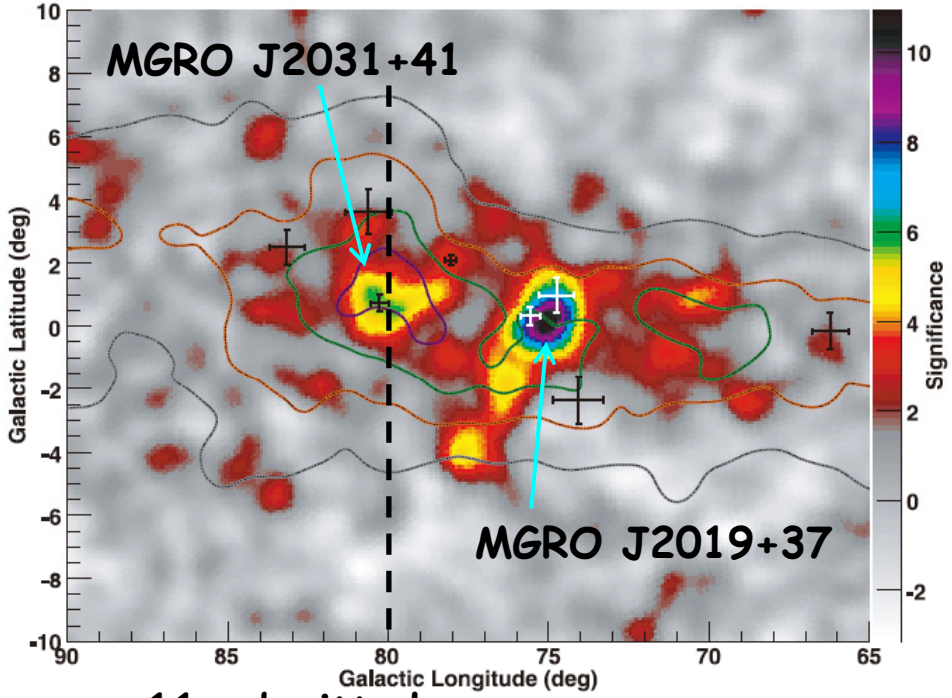



Abdo+07, ApJL 658, 33
Abdo+08, ApJ 688, 1078

# The Cygnus Region (Fermi)

- **Very rich region of massive-star formation at 1.4 kpc**
- **Detailed study by Fermi-LAT**
  - **GeV diffuse (on average) consistent with local CR spectrum, despite the conspicuous star formation activity**

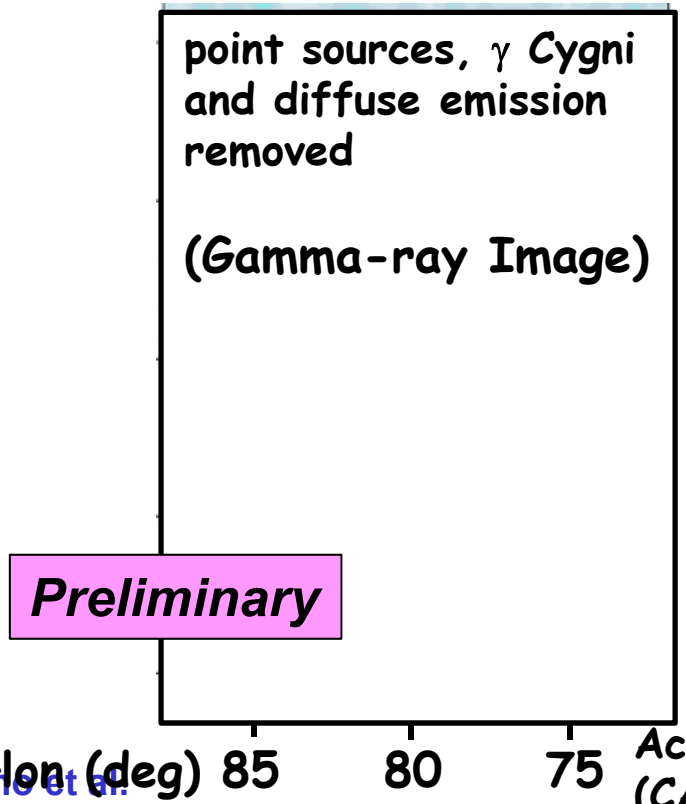


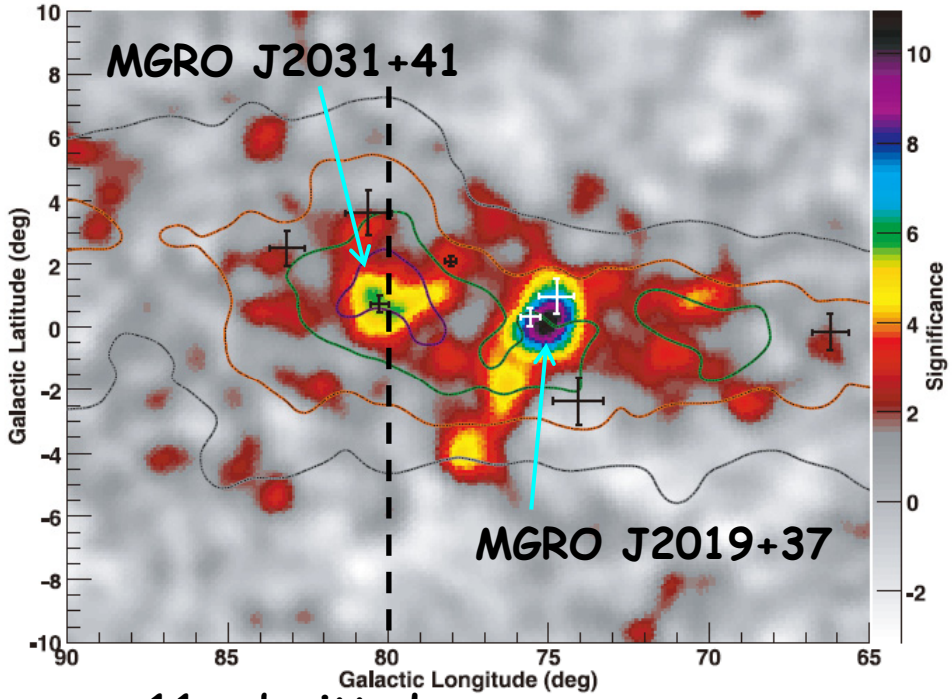




Ackermann+11 submitted
(CA: Tibaldo, Grenier)

# The Cygnus Region (Fermi)

- Very rich region of massive-star formation at 1.4 kpc
- Known sources and diffuse gammas subtracted
  - Extended hard (>10 GeV) excess revealed in OB2 association
  - Spatial relation with infrared suggests the interstellar origin

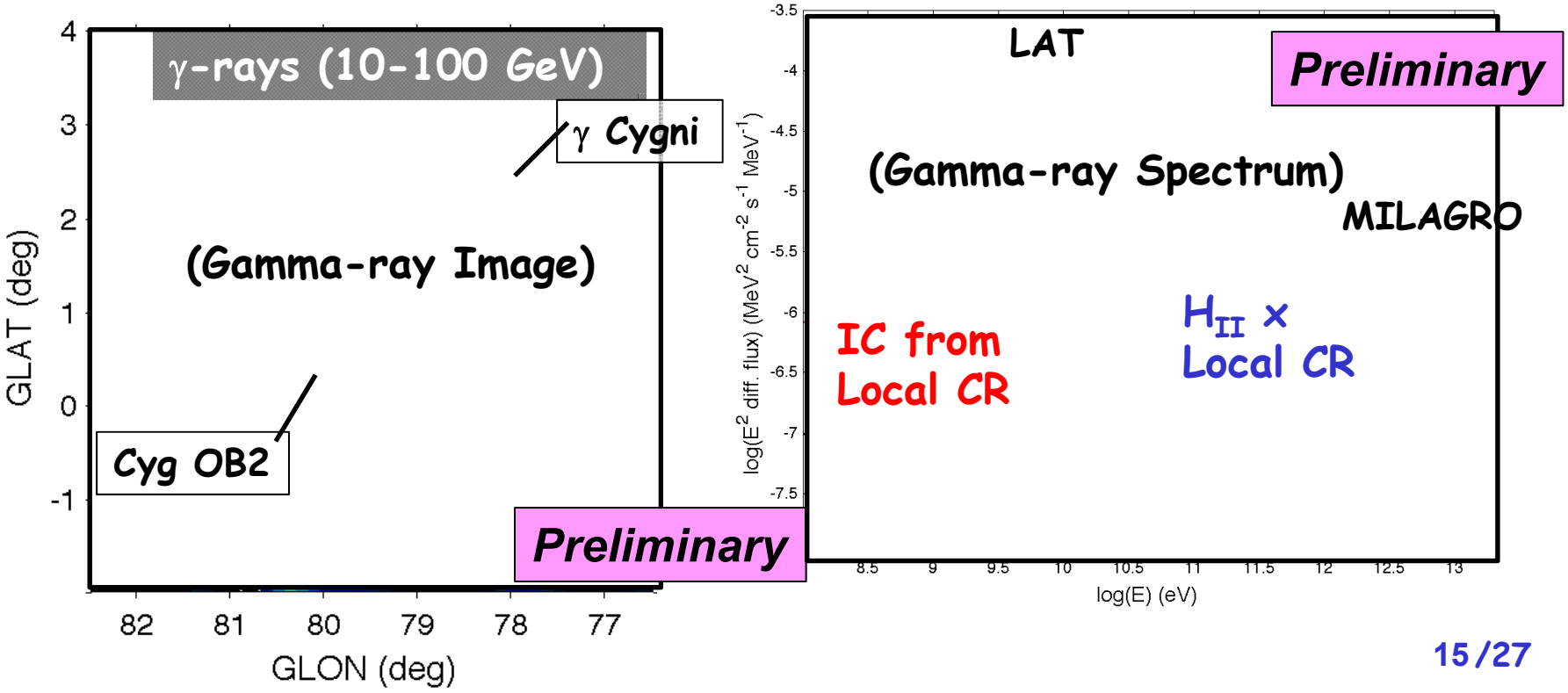



Ackermann+11 submitted
(CA: Tibaldo, Grenier)

# Energy Spectrum

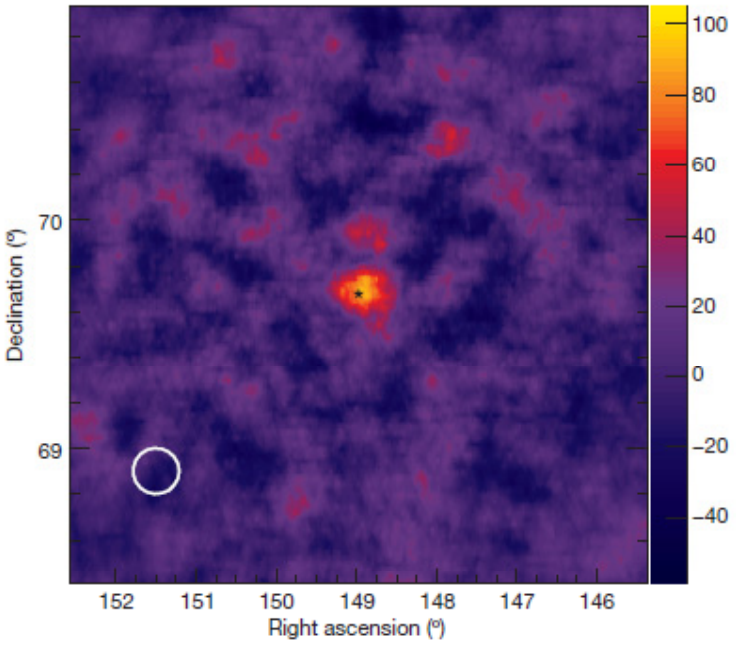
- CRs with local spectrum are too weak or too soft
- Hard, freshly accelerated CRs are required
  - $E^{-2.4}$ (hadron) or $E^{-2.7}$ (lepton)
  - their origin and propagation to be studied by GeV/TeV obs.



# Starburst Galaxies

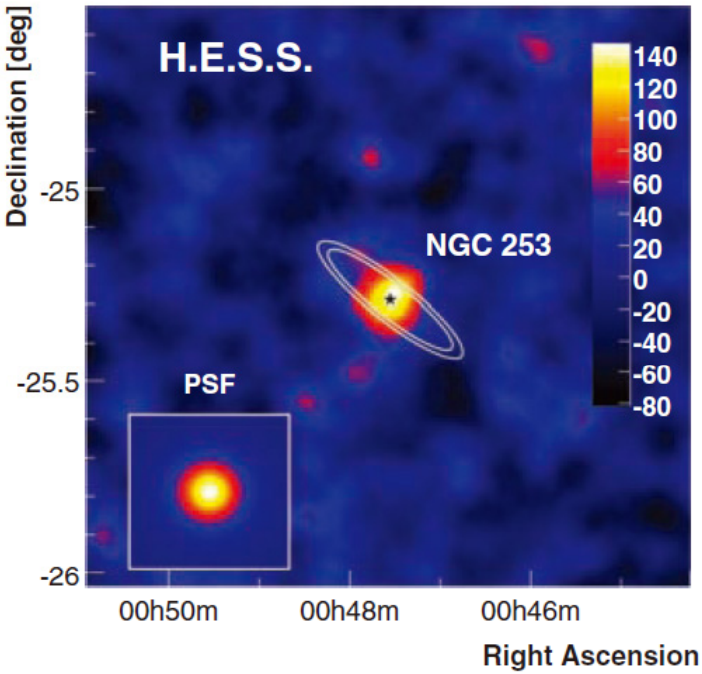
- High gas density and star-formation rate
- Detected by H.E.S.S. (NGC 253) and VERITAS (M82) in TeV

M82 (VERITAS)




Acciari+09, Nature 462, 770

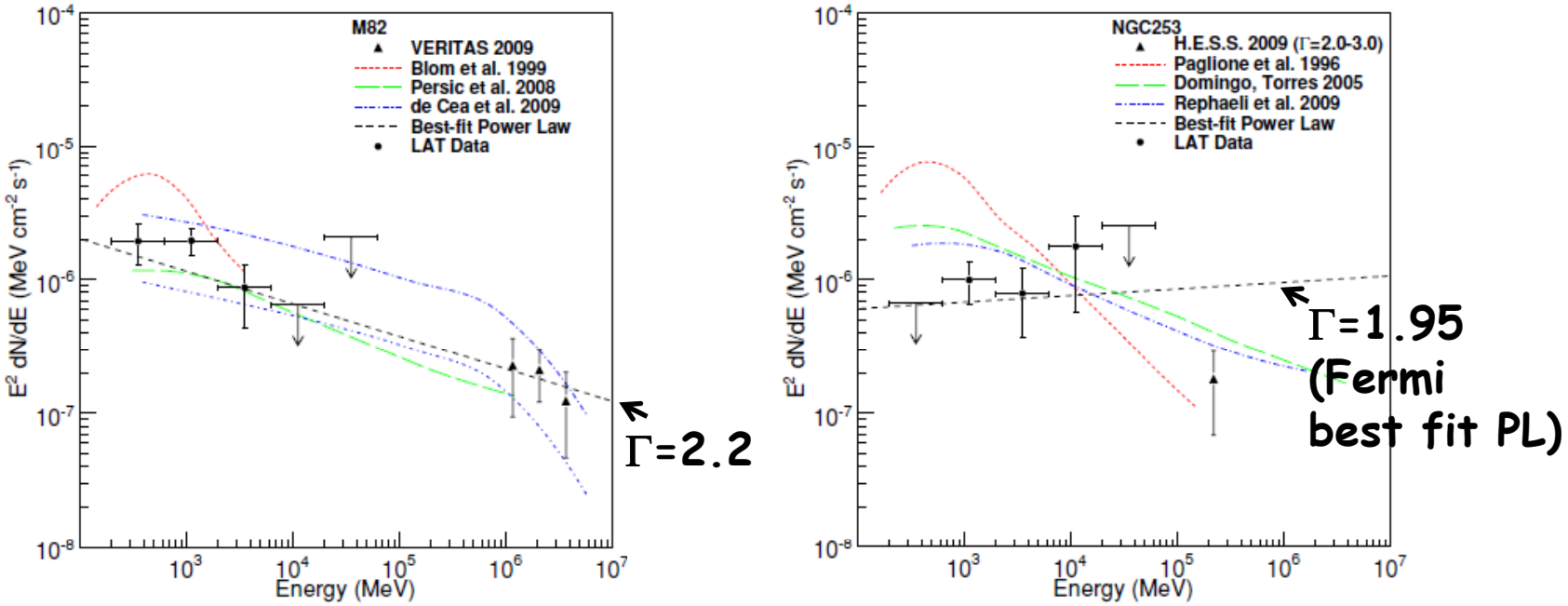
NGC253 (H.E.S.S.)




Acero+09, Science 326, 1080

# Starburst Galaxies

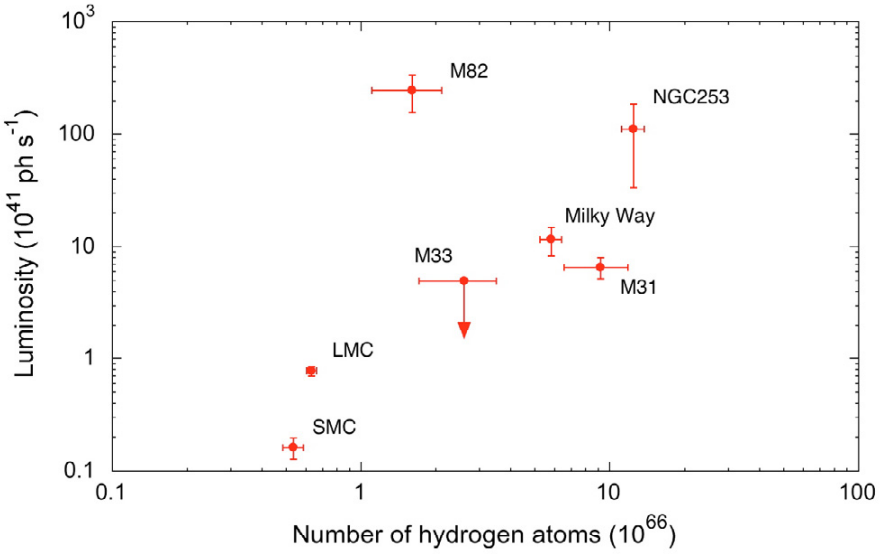
- High gas density and star-formation rate
- Detected by H.E.S.S. (NGC 253) and VERITAS (M82) in TeV
- Hard spectrum by Fermi+IACT

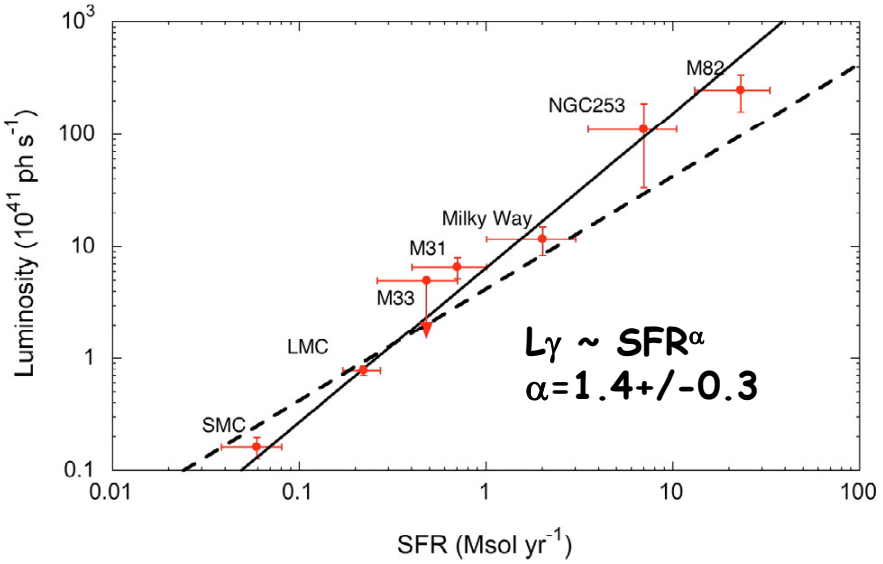



Abdo+10, ApJL709, 152

# SB + Local Group Galaxies

- LMC, SMC and M31 detected by Fermi-LAT
- Correlation between SFR and Lγ over wide range in galaxy properties.
- Lγ less correlated with gas mass.

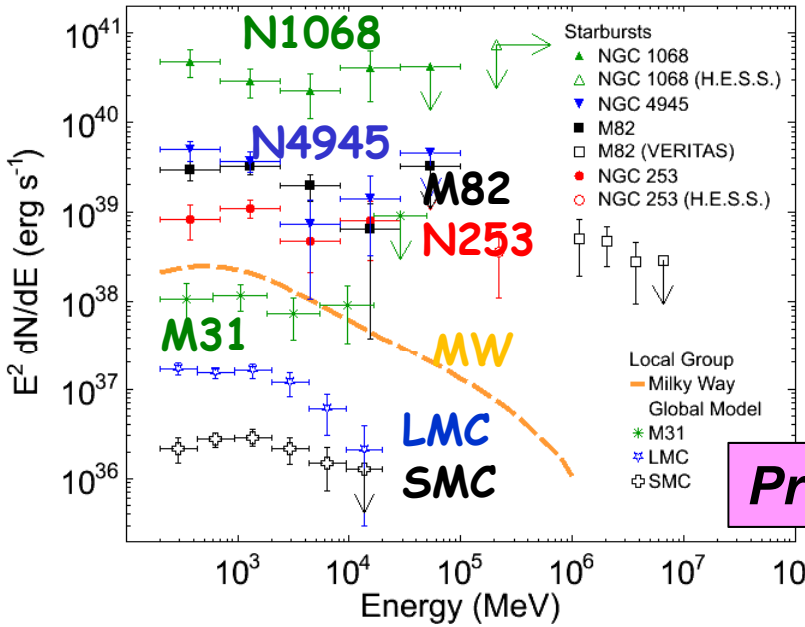


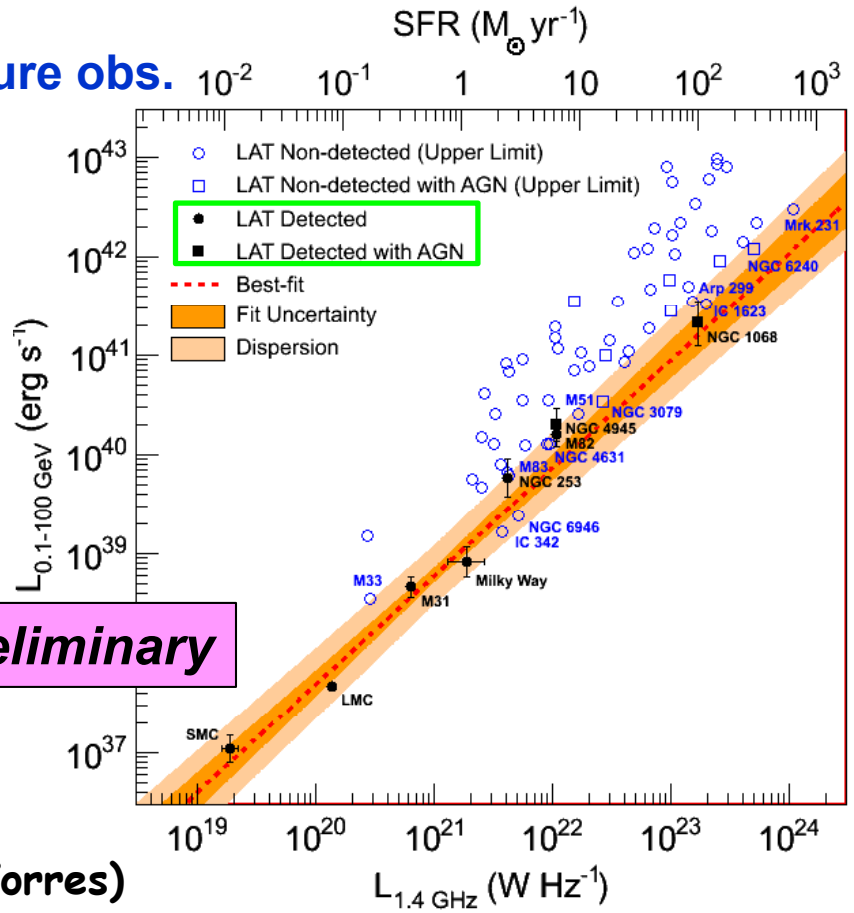




Abdo+10, A&A 523, L2
(CA: Bechtol, Knodlseder, Martin)

# Recent Update

- **A sample of 69 is examined: confirm the relation between star-formation rate and Lγ**
- **SFR-Lγ relation and hard spectrum implies hadron calorimetry**
  - **NB MW is escape limited**
  - **need theoretical work and future obs.**




**Preliminary**

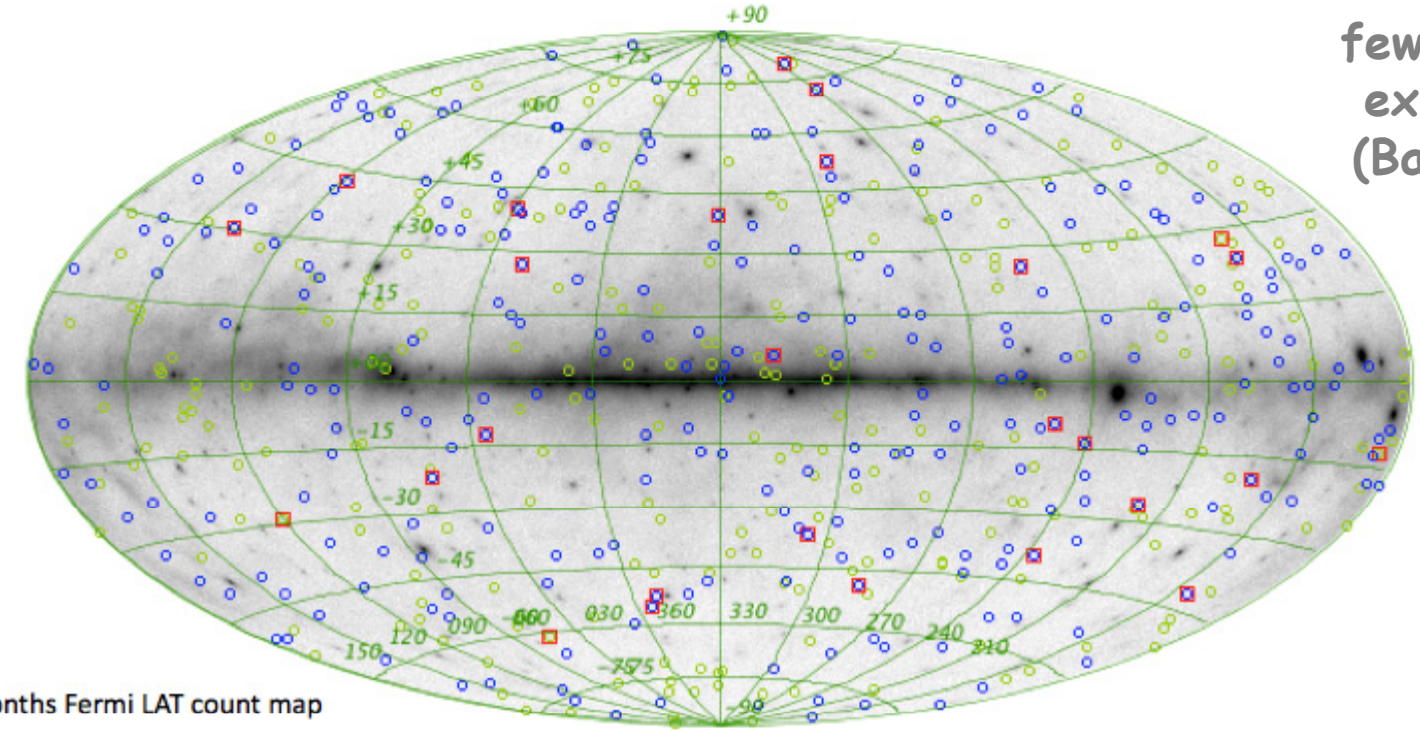
**Ackermann+11 submitted**
**(CA: Bechtol, Cillis, Funk, Torres)**

T. Mizuno et al.

# Fermi GRBs as of 2011-08-01

- **In 3 years**
  - **682 GBM GRBs (345 in LAT FOV)** ~0.6/day
  - **32 LAT GRBs (19 with >10 photons >100 MeV)** ~0.6/month

fewer than expected (Band+09)




11 months Fermi LAT count map

***Preliminary***

# Summary of LAT GRBs

| GRB Name | GBM T90 | N Pred. Events (>100MeV, Trans.) | HE Delayed Onset? | Long Lived HE Emission? | Maximum Energy (GeV) | Arrival time of the highest events (seconds since trigger) | Redshift |
|---|---|---|---|---|---|---|---|
| GRB080825C | Long | 10 | √ | √ | 0.6 | 28.3 | - |
| GRB080916C | Long | 188 | √ | √ | 13.2 | 16.5 | 4.35 |
| GRB081006 | Long | 13 | √ | √ | 0.8 | 1.8 | - |
| GRB081024B | Short | 11 | √ | √ | 3.1 | 0.6 | - |
| GRB081207 | Long | LLE | - | - | - | - | - |
| GRB090217 | Long | 17 | √ | √ | 1.2 | 179.1 | - |
| GRB090227B | Short | 3 | - | - | 0.0 | 0.0 | - |
| GRB090323 | Long | 30 | √ | √ | 7.5 | 195.4 | 3.57 |
| GRB090328 | Long | 50 | √ | √ | 24.5 | 261.7 | 0.736 |
| GRB090510 | Short | 186 | √ | √ | 31.3 | 0.8 | 0.903 |
| GRB090531B | Short | LLE | - | - | 1.6 | 115.2 | - |
| GRB090626 | Long | LLE | √ | √ | 2.1 | 111.6 | - |
| GRB090902B | Long | 314 | √ | √ | 33.4 | 81.8 | 1.822 |
| GRB090926 | Long | 249 | √ | √ | 19.6 | 24.8 | 2.106 |
| GRB091003 | Long | ~30 | √ | √ | 2.8 | 6.5 | 0.897 |
| GRB091031 | Long | 15 | √ | √ | 1.2 | 79.8 | - |
| GRB100116A | Long | 14 | - | √ | 13.1 | 296.4 | - |
| GRB100225A | Long | LLE | - | - | - | - | - |
| GRB100325A | Long | 6 | - | √ | 1.9 | 71.4 | - |
| GRB100414A | Long | 27 | √ | √ | 4.7 | 288.3 | 1.368 |
| GRB100724B | Long | 22 | - | - | 0.2 | 61.8 | - |
| GRB100728A | Long | 4 | - | - | 0.1 | 81.2 | - |
| GRB100728A | Long | LLE | - | - | 0.1 | 81.2 | - |
| GRB101014A | Long | LLE | - | - | - | - | - |
| GRB101123A | Long | LLE | - | - | - | - | - |
| GRB110120A | Long | 5 | - | - | 1.8 | 72.5 | - |
| GRB110328B | Long | LLE | - | - | 1.6 | 514.7 | - |
| GRB110428A | Long | 17 | √ | √ | 2.6 | 14.8 | - |
| GRB110529A | Short | LLE | - | - | - | - | - |
| GRB110625A | Long | 12 | - | √ | 2.4 | 272.4 | - |
| GRB110721A | Long | 29 | - | √ | 1.7 | 0.7 | 0.38 |
| GRB110731A | Long | 65 | √ | √ | 3.4 | 436.0 | 2.83 |

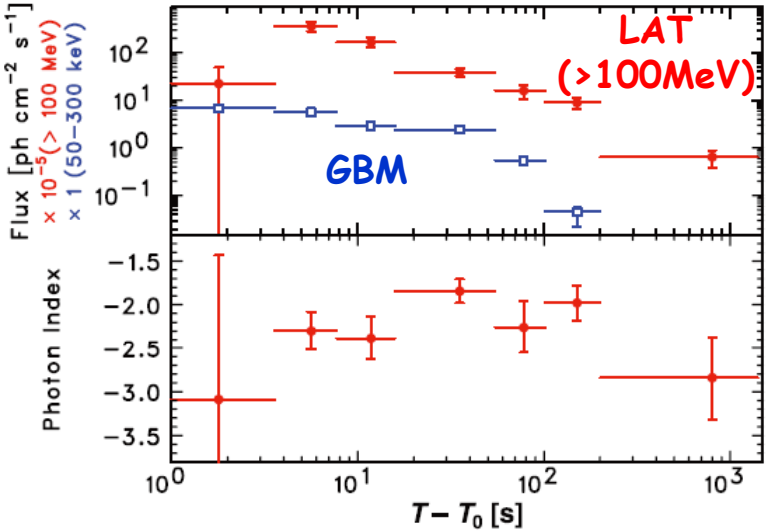
- 32 GRBs by LAT, 19 with >10 γs above 100 MeV
- Most of GRBs show <u>delayed HE onset</u> and <u>HE afterglow</u>
- Some bursts have an extra spectral component

***Preliminary***

T. Mizuno et al.

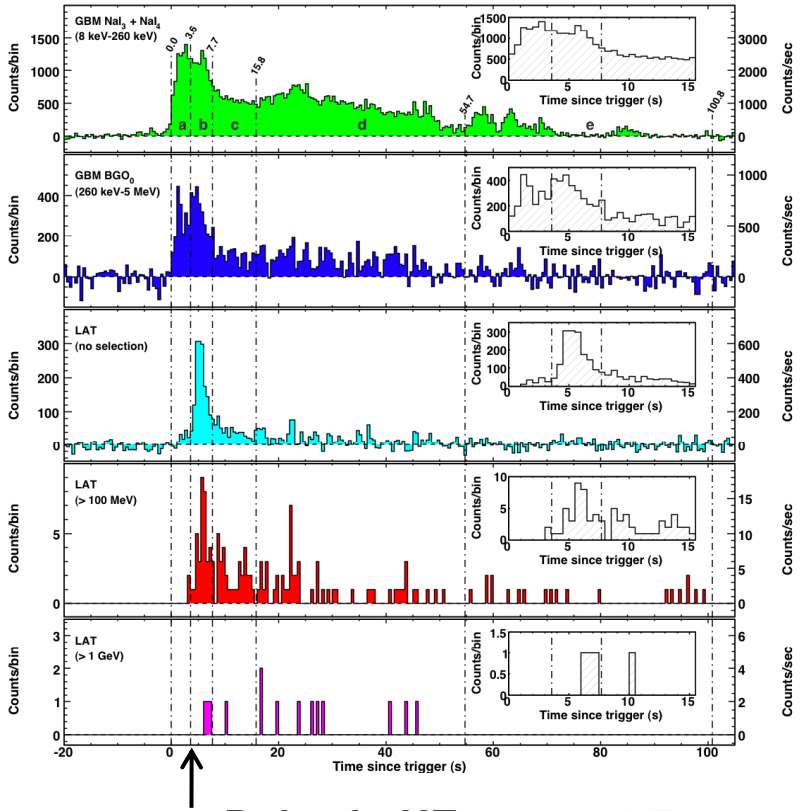
# Common feature of GRBs

- **Delayed HE onset and temporary extended emission are commonly seen**
- **Some GRBs show extra spectral component (090510, 090902B, 090926A)**




***GRB 080916C (long)***

*Abdo et al. 2009, Science 323, 1688*



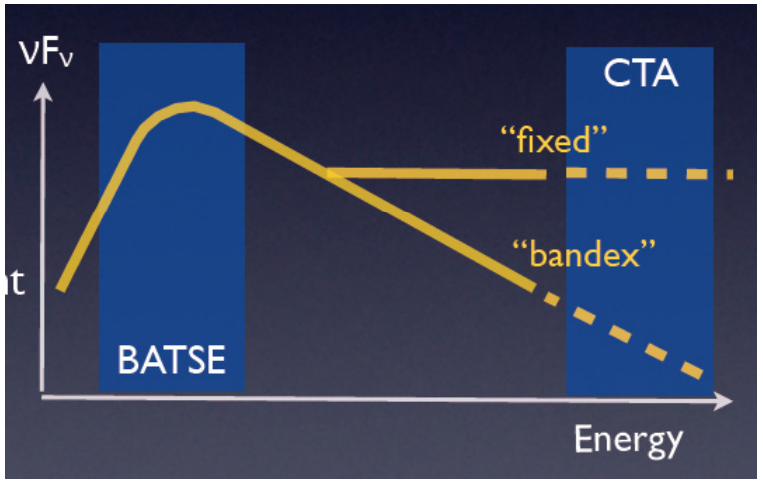

**Delay in HE onset: 4-5 s**

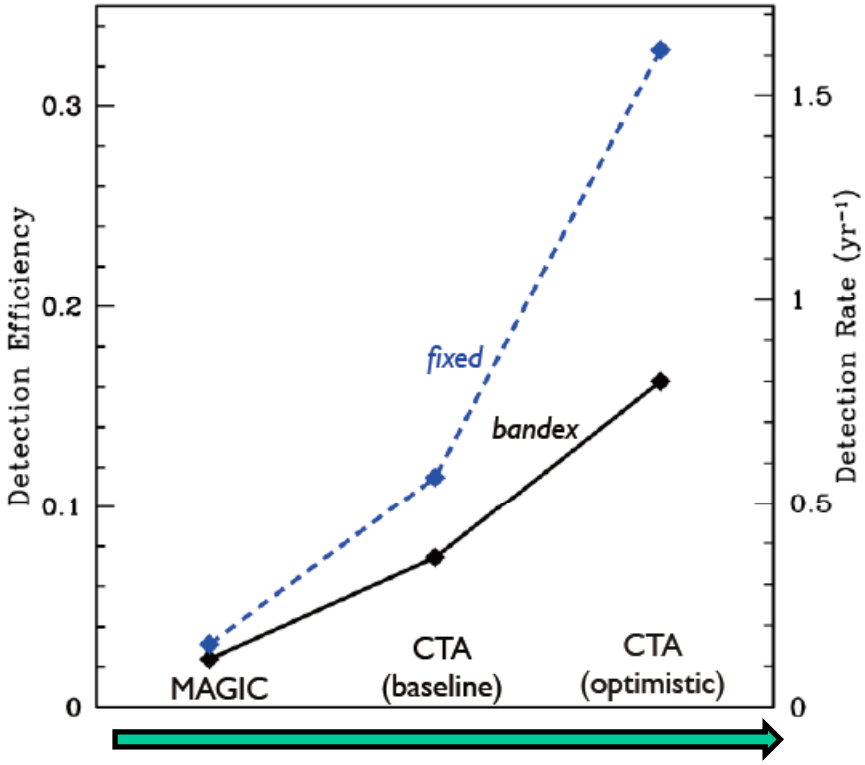
- LAT Aeff ~ 0.8m$^2$ (<$10^{-4}$ of CTA Aeff)
- Large Aeff is of great benefit to study extra component, extended emission and quantum Gravity.

# Prospect of GRB with CTA

- ~1 GRB/yr
- Energy threshold is important

Bouvier+11
(ICRC2011)



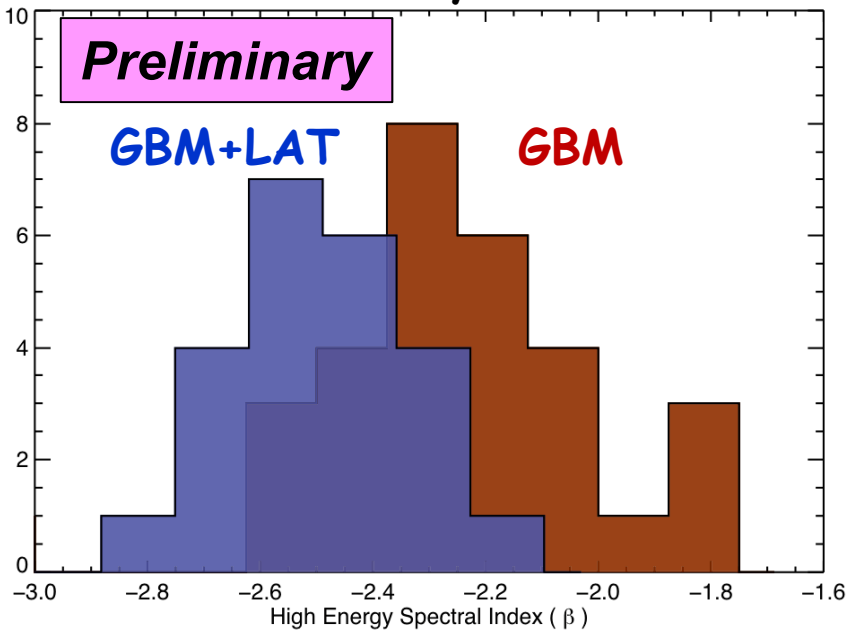




lower Eth and larger Aeff

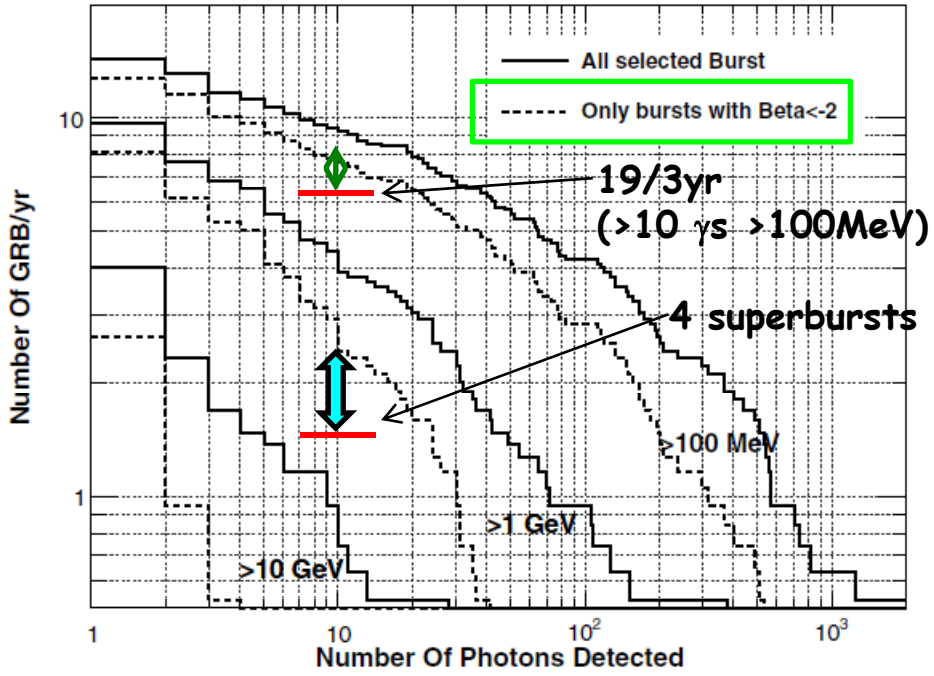
# Caution on Detection Rate Estimate

- **10% of GBM GRBs in LAT FOV are detected by LAT**
  - **lower than expected (single PL), particularly in GeV**
  - **GBM+LAT joint fit leads to softer β**

30 GBM-bright samples undetected by LAT



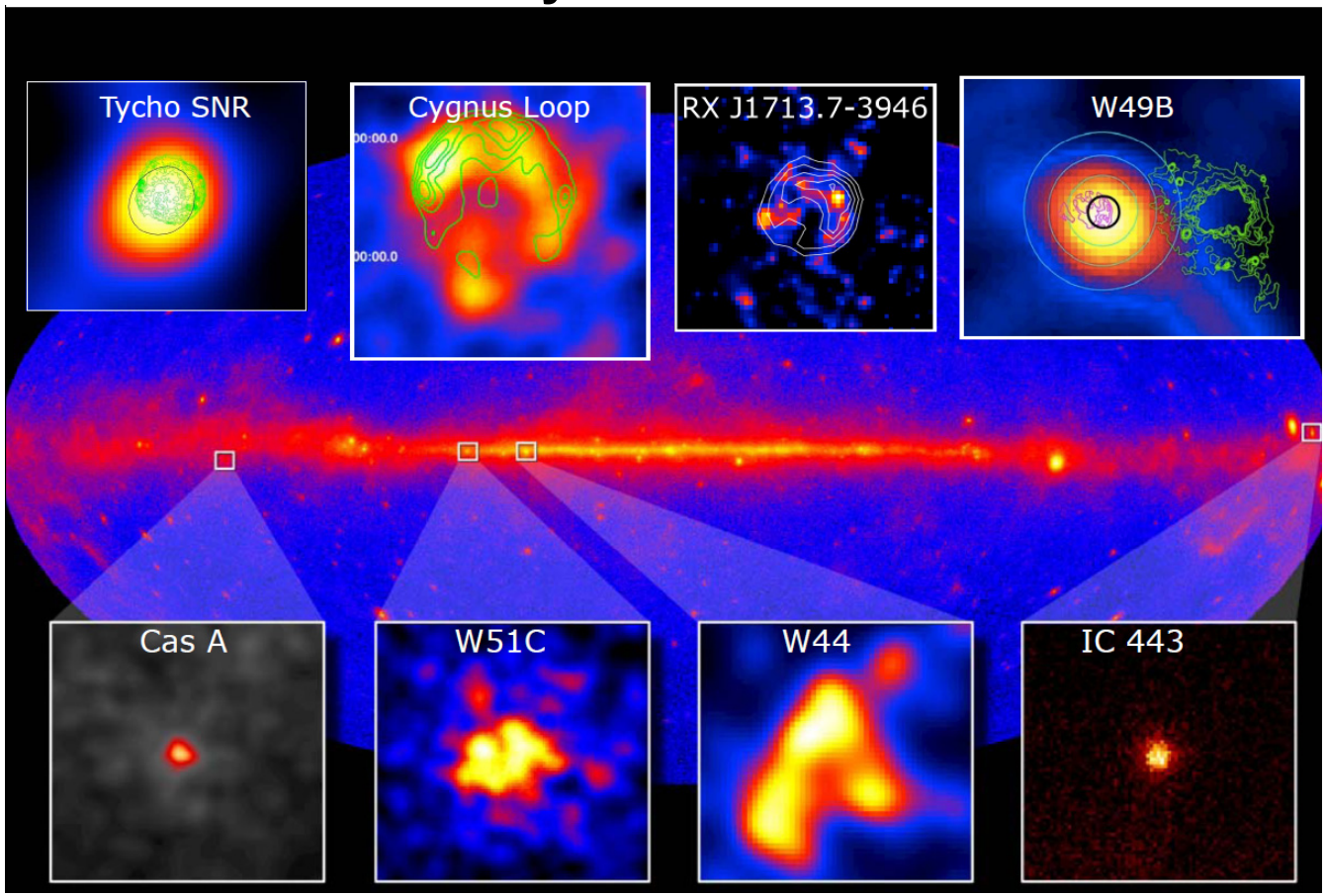

Connaughton+11 (ICRC2011)




Band+09, ApJ 701, 1673

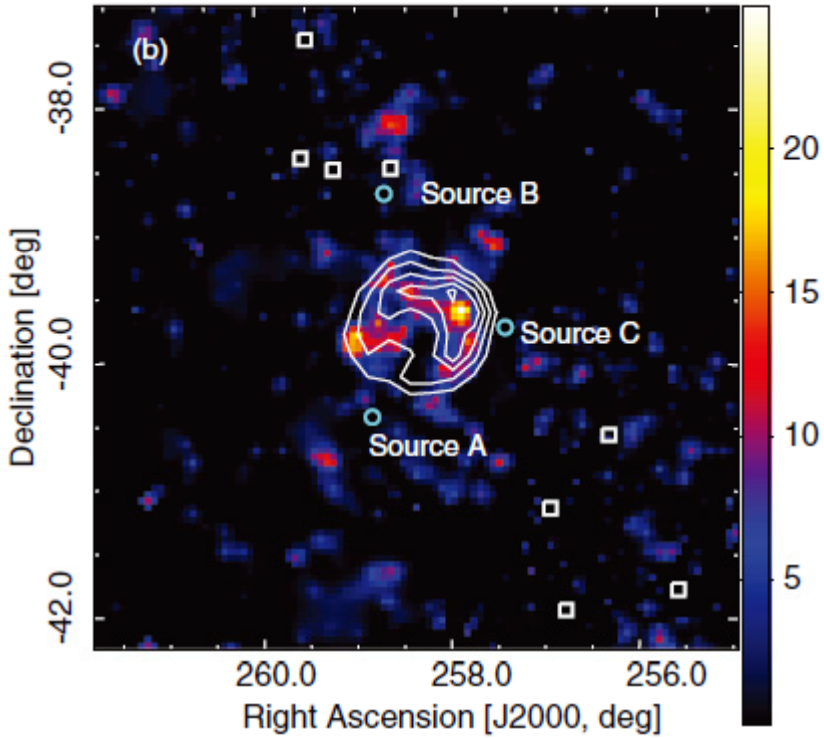
# SNRs seen by Fermi-LAT

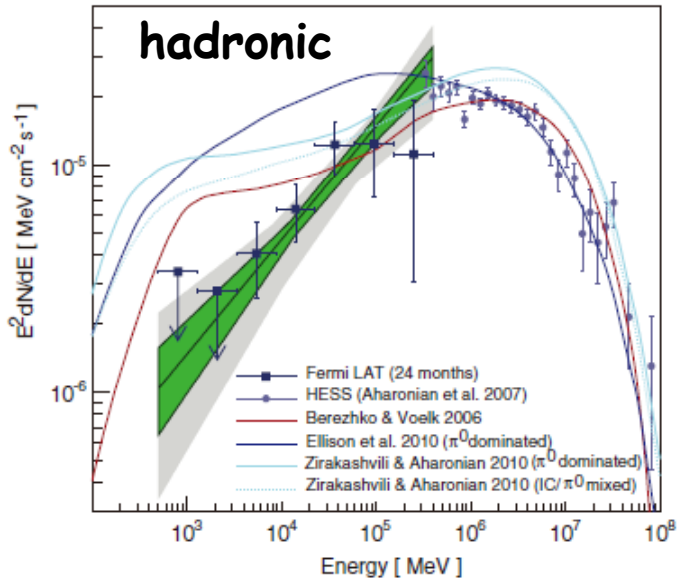
- ten 2FGL sources are now identified as, or associated with SNR (# of possible association ~60)
- Hadronic scenario is usually favored

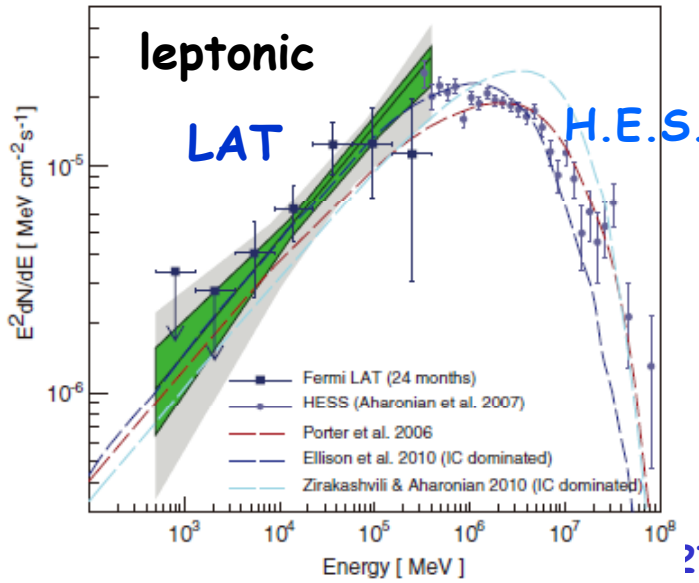


# RXJ1713.7-3946

- GeV γ-ray excess above diffuse emission correlates with TeV γs
- Broadband spectrum favors leptonic origin as the emission mechanism




Abdo+11, ApJ 734:28
(CA: Ackermann, Funk, Uchiyama)

# Summary

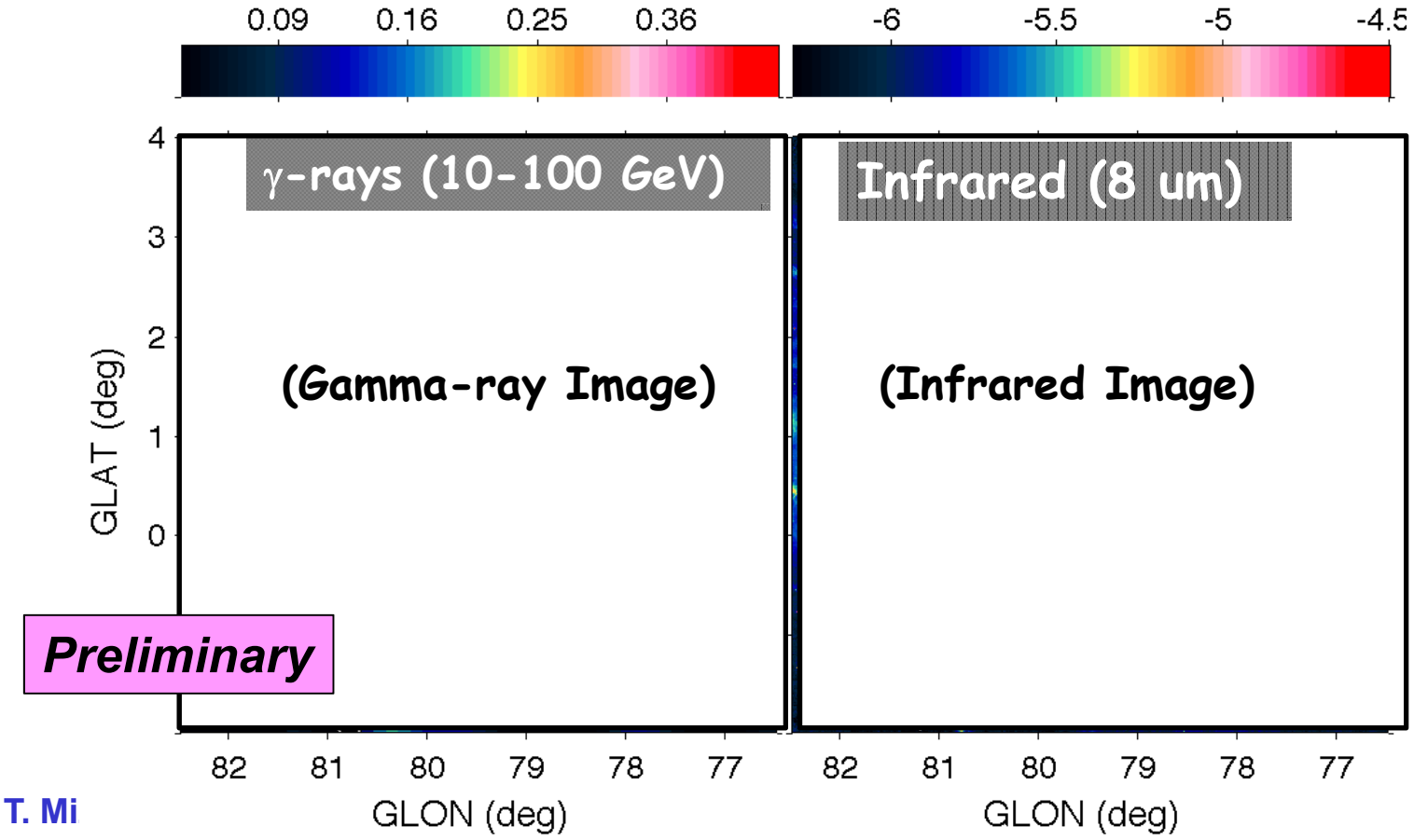
- フェルミは順調に観測. 高い生産性.
- 最近の成果をいくつか紹介
  - 加速されたばかりの宇宙線 in Cygnus Region
  - 星生成銀河のSFR-Lγ 関係
  - SNRのGeV/TeVスペクトルと放射機構
- いずれもTeVのデータが重要
- GRBもCTAへの期待大. 見積もりには注意.

**Thank you for your Attention**

# Backup Slides

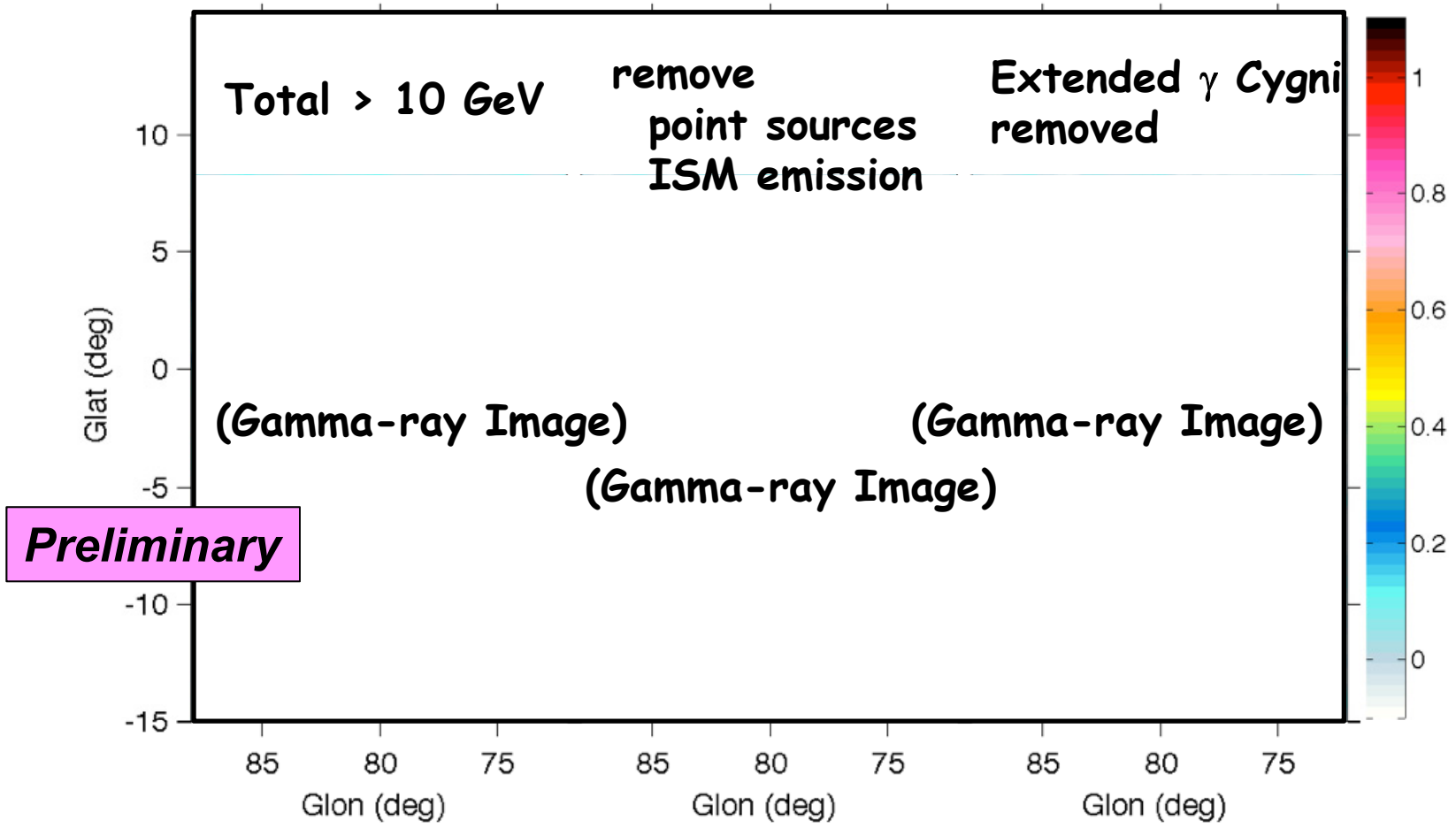
# Morphology

- **γ-ray excess fills the cavities carved by stellar winds and ionization fronts**
  - **likely interstellar origin**



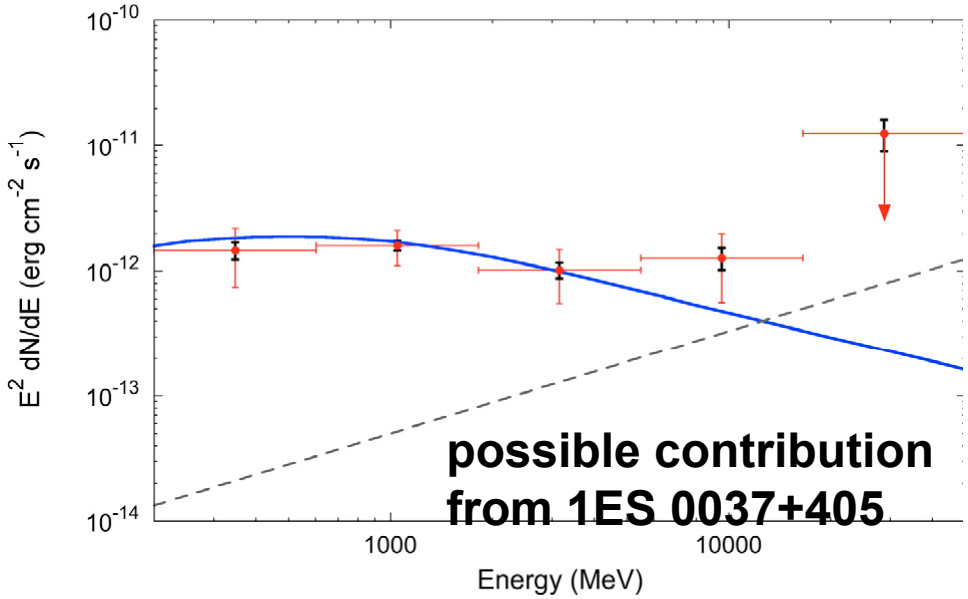
# The Cygnus Region (Fermi)

- **Extended excess (>10 GeV) is revealed**

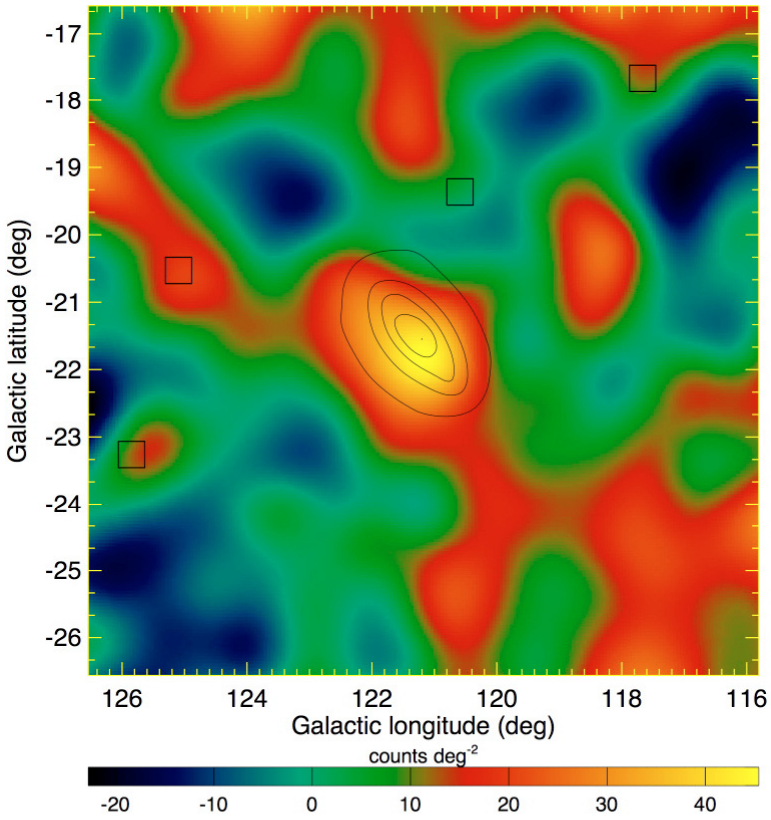


# M31 Morphology and Spectrum

M31 Spectrum vs. normalized model of MW

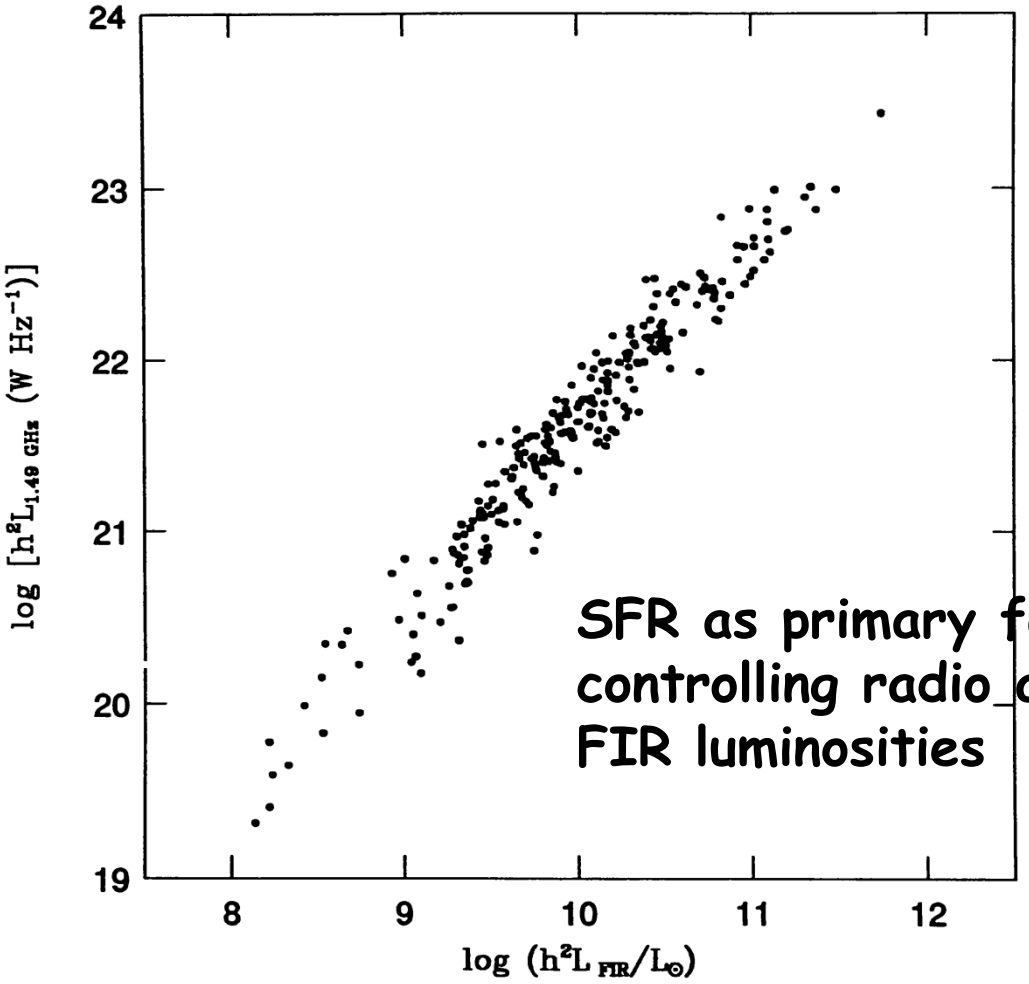



BG-subtracted LAT image
Contour: IRIS 100 um



# FIR-radio Relation

- **FIR vs. Radiocorrelation**

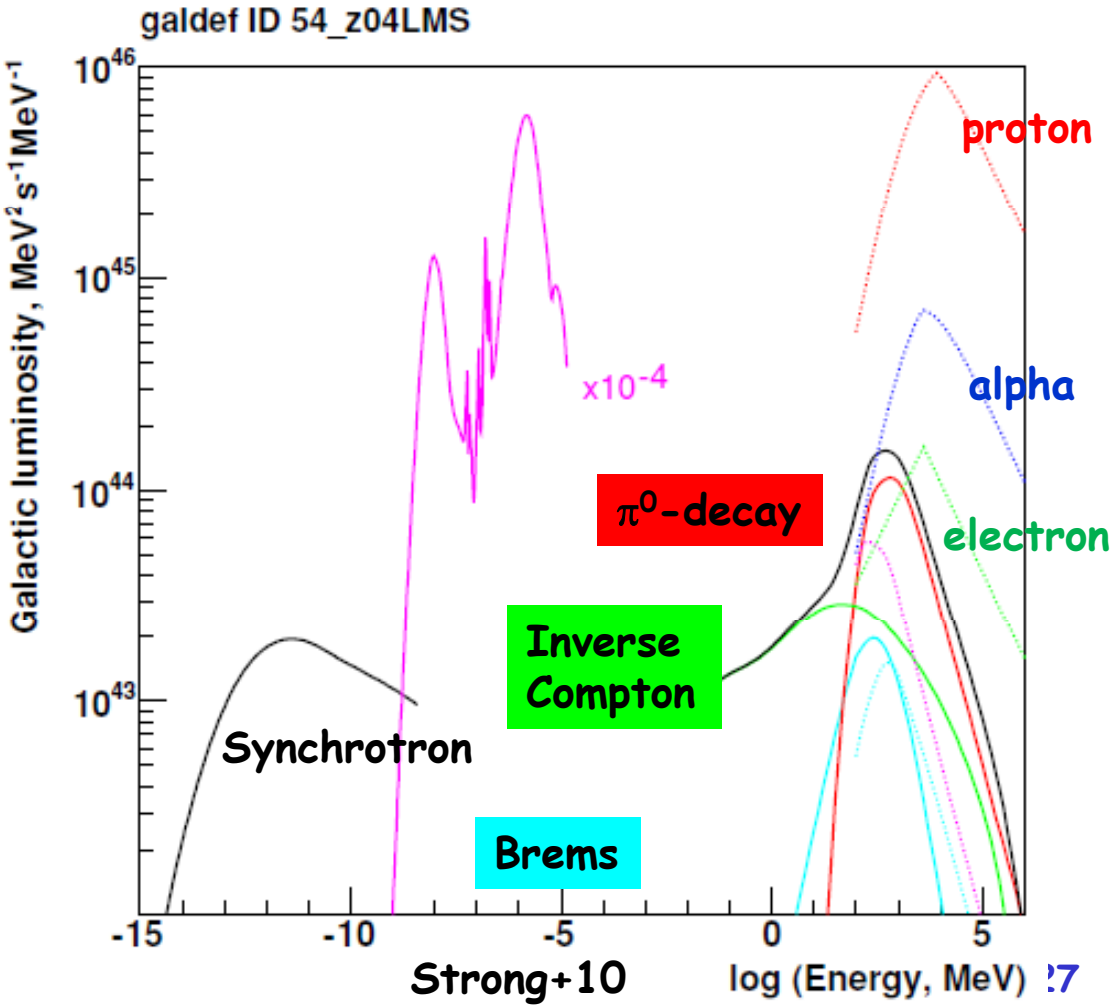



SFR as primary factor controlling radio and FIR luminosities

Condon92

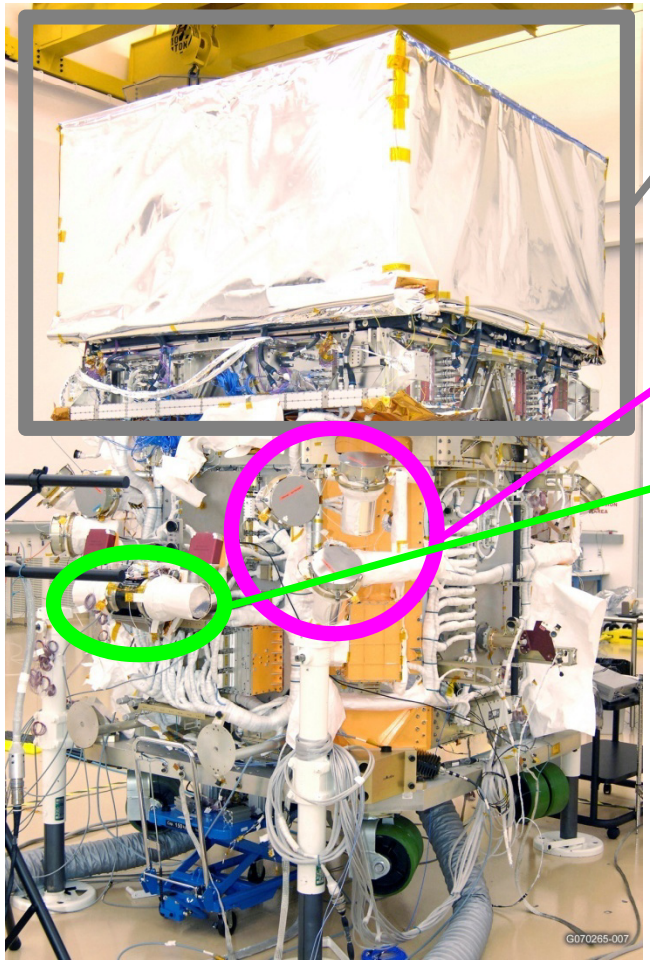
# CR-induced Luminosity of MW

- MW is nearly a CR electron calorimeter, if IC is taken into account
- Conversion eff. ~1% for protons




T. Mizuno et al.

# The *Fermi* Observatory (2008-)



**LAT : 対生成型ガンマ線望遠鏡**

トリガ、位置決定、スペクトル取得

20 MeV – 300 GeV

**GBM :広視野バーストモニタ**

12 NaI

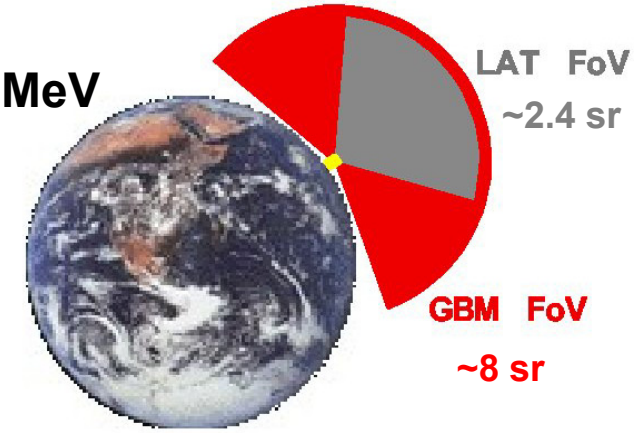
トリガ、位置決定、スペクトル

8 keV – 1 MeV

2 BGO

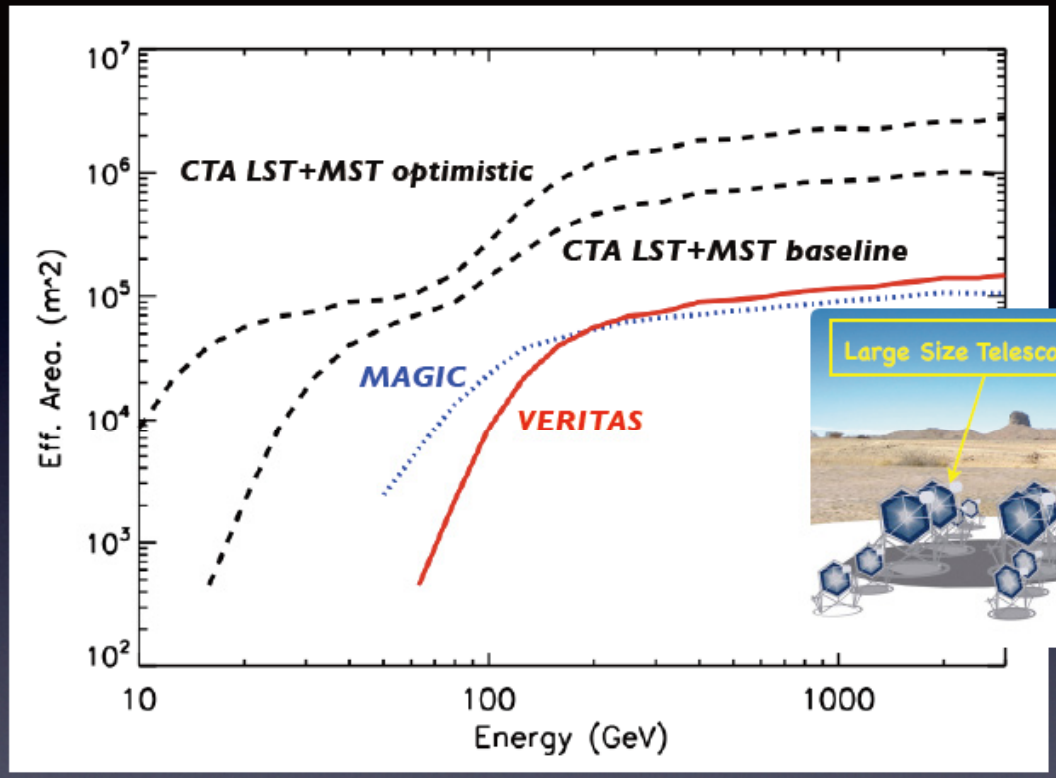
スペクトル

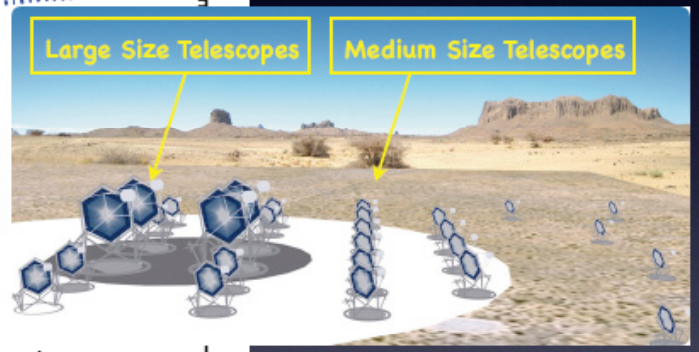
150 keV – 40 MeV



# Simulated CTA Performance

## Simulated CTA performance

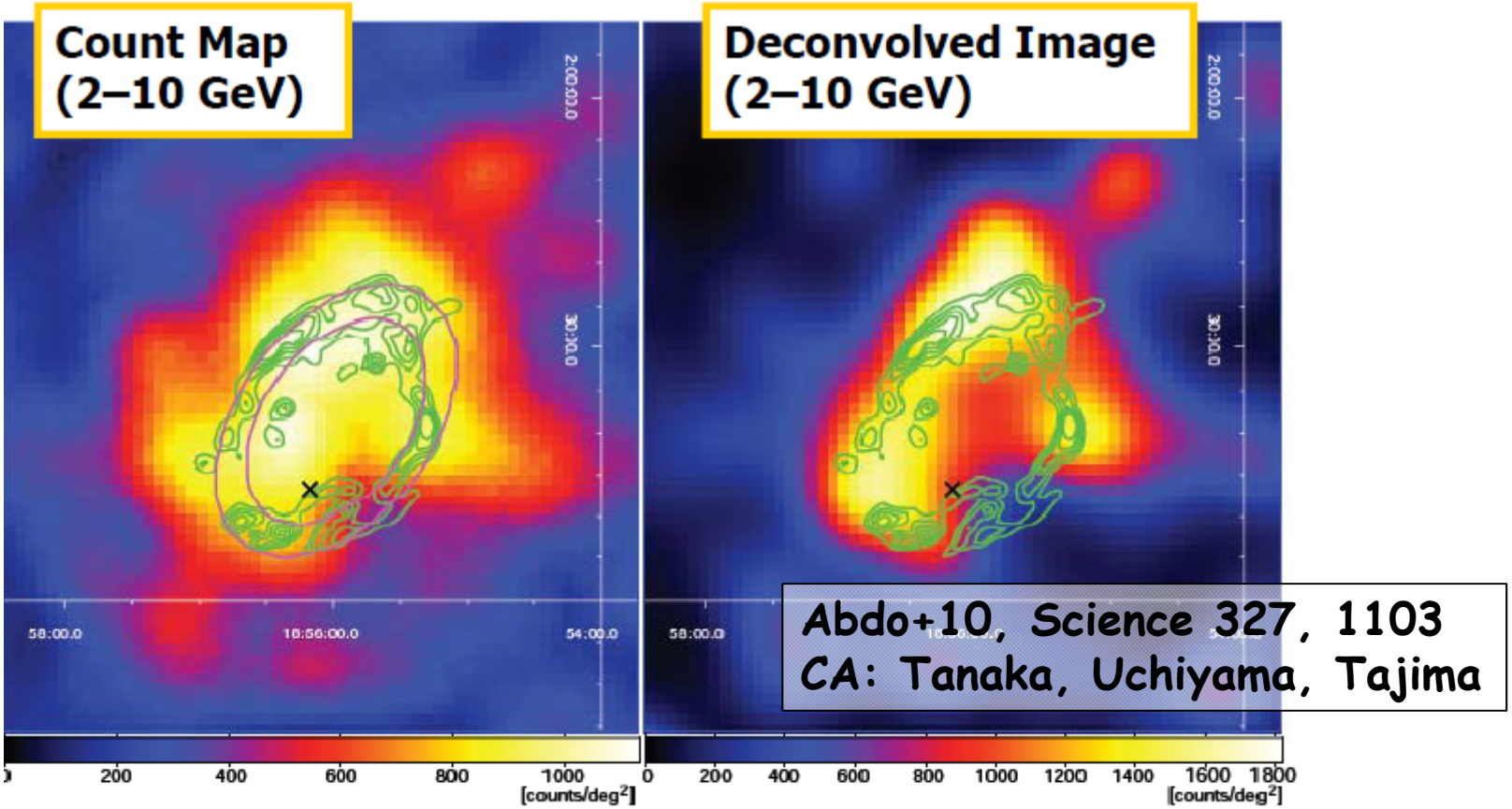



Bouvier+11 (ICRC2011)

- CTA performance (Eff.Area + Bkg Rate) estimated from simple scaling of VERITAS performance
- **CTA baseline**: 4 LSTs ($E_{th}$ = 25 GeV) + 25 MSTs
- **CTA optimistic**: 4 LSTs ($E_{th}$ = 10 GeV) + 75 MSTs (+ 3 times lower bkg rate)
- $E_{th} = E_{th}(\text{Zenith}=0) \times \cos(\text{Zenith})^{-3.0}$

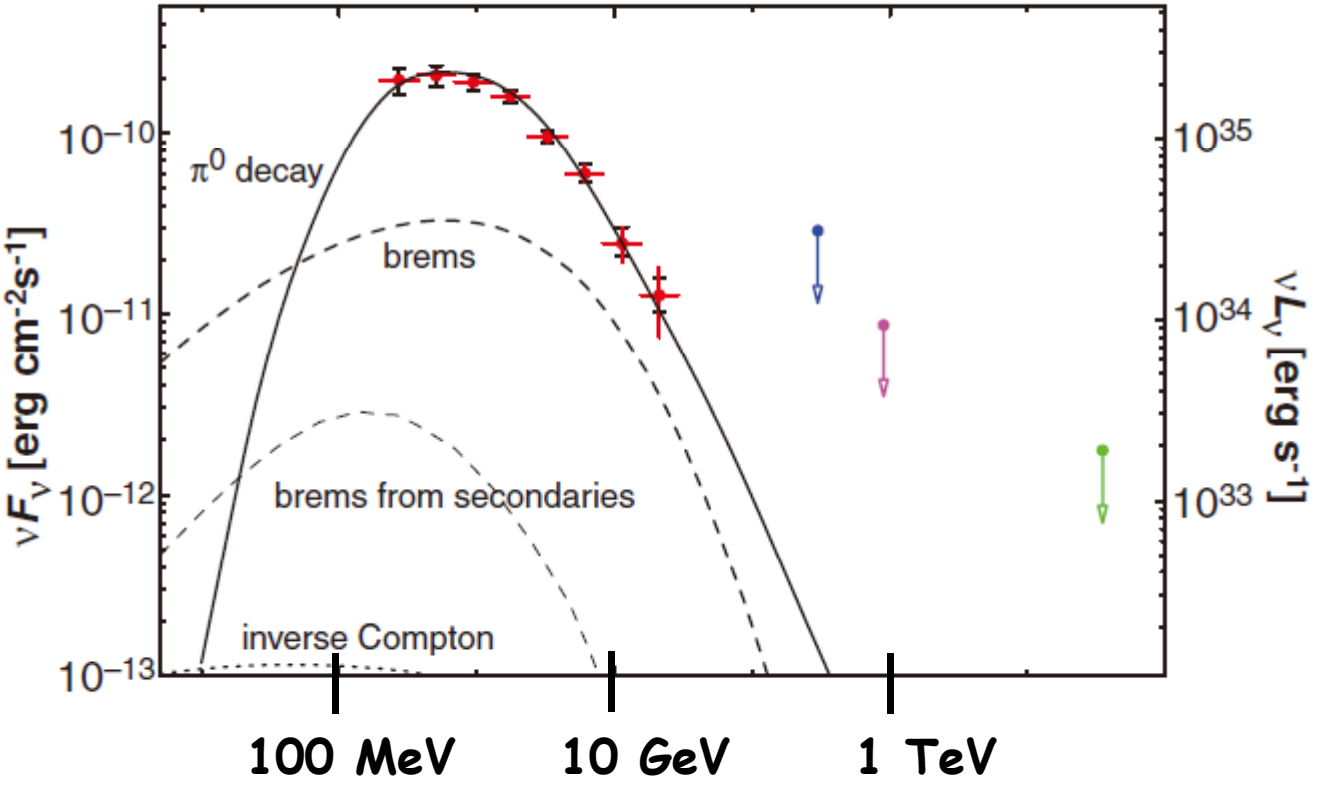
# LAT view of W44




x印はパルサーの位置
緑のコントアは衝撃波に励起された分子雲

- 高密度の分子雲からγ線が放射

# LAT Spectrum & modeling




- スペクトルは陽子起源が良く合う

T. Mizuno et al.